

SUMMARY OF REQUIREMENTS FOR THE COLLECTION SYSTEM

The collection system refers to the process by which a representative system is collected from the point of extraction, transferred to the analytical system, and analyzed. The sample must be handled in a manner that preserves its original physical form and chemical composition. Any contaminants in the sample must be removed prior to analysis.

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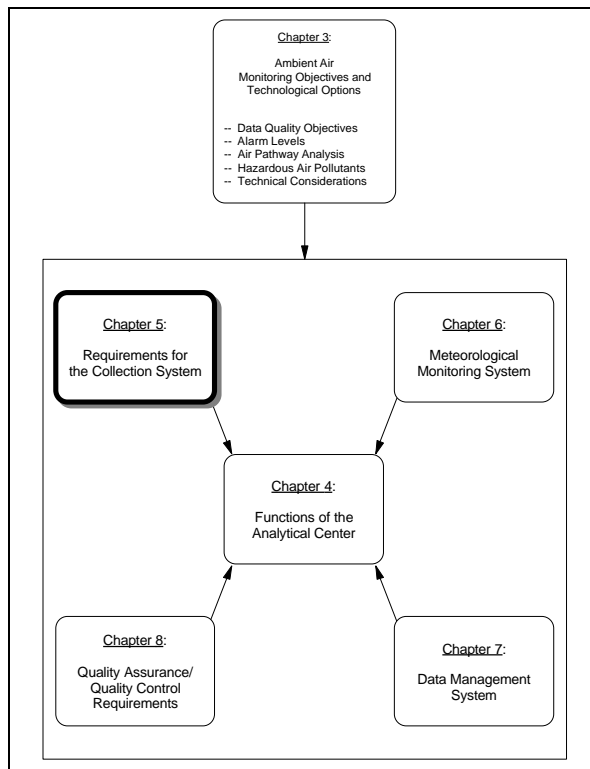
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The goal of the collection system is to extract a sample that is representative of the ambient air at the site. Chapter 5 discusses the components and requirements of this system that are necessary to ensure sample integrity.



5-1. Introduction

The goal of any perimeter air monitoring system at an HTRW site is to collect a representative sample from the point of extraction, transfer that sample to the analytical system, and determine the concentration of the analytes of concern without compromising sample integrity. The extracted sample should represent a subset of the ambient air at the HTRW site and be collected and handled in a manner that preserves its original physical form and chemical composition and that prevents changes in the concentration of the analytes from outside contamination. If other species are present in the sample gas that interfere, they must be removed prior to analysis. This removal may involve filtering or scrubbing the gas sample before delivering it to the analyzer compartment in the Analytical Center. It should be remembered during the FFMS system design that depending on the site environment, components of interest and collection system characteristics, it may not be necessary to heat the sample transport lines.

5-2. System Design, Structure, and Components

The extraction of a representative sample from a point and its transport to the analyzer in the Analytical Center as part of a volatile FFMS at a HTRW site must involve three major subsystems to ensure the integrity of the sample. The three subsystems, as identified in Table 5-1 and illustrated in Figure 5-1, are sample inlet, sample transport, and sample conditioning.

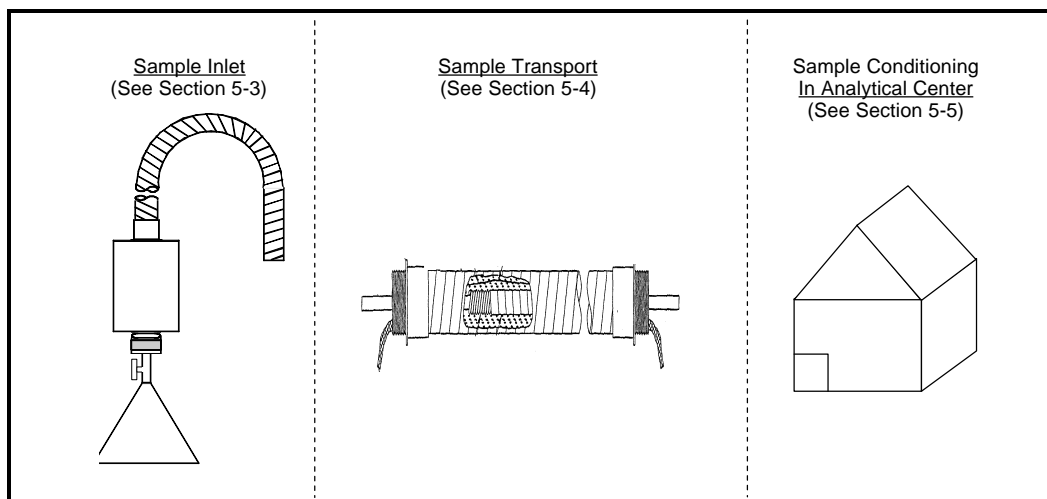


Figure 5-1. Example components of the sample collection system for FFMS

Table 5-1
Example of Subsystems of the Collection system of a Real-time VOC FFMS

Sample Inlet	Sample Transport	Sample Conditioning
-Probe -Primary Coarse Particulate Filter -Audit Gas Connection	-Heated Transfer Lines -Sample Pumps -J-Boxes for Joining Heat Trace Line Segments	-Moisture Removal -Secondary Fine Particulate Filter -Calibration Gas System Injection
-Flow Measurement Connection		-Flow Measurement Control Device

- **Sample inlet**--The purpose of the sample inlet system is to extract a representative sample from the ambient air, minimize the influence of moisture, and remove coarse particulate matter from the gas stream to prevent contamination of downstream components. Figure 5-2 illustrates a typical inlet configuration.
- **Sample transport**--A sample transport system provides the ability to pass the ambient gas sample from the point of extraction to the conditioning system through temperature controlled samples lines. The sample transport components are the heat-trace lines, J-boxes, and pumping system. Figure 5-3 illustrates heat-trace sample lines as part of the extractive system.
- **Sample conditioning**--the objective of the sample conditioning system is to condition the sample stream by removing secondary fine particles and moisture prior to entering the analytical system in the Analytical Center.



Figure 5-2. Typical inlet configuration of a perimeter volatile organic sampling system

5-3. Sampling System Inlet Particulate Control

a. Introduction. It is imperative that with any ambient real-time FFMS for volatile organics some attention be given to particulate control prior to sample analysis. Most extractive gas analyzers and organic species analyzers require the removal of particulate matter.

Particulate matter can interfere with the sample concentration and analysis, thus jeopardizing the validity of the gas concentration acquired. The removal of particulate matter in a fixed-fenceline extractive system is performed in two stages. First, the coarse particles are removed at the probe inlet to minimize clogging of sample lines. Second, a fine filter is employed at the end of the sample line, usually at the analyzer inlet in the Analytical Center, to remove fine particles (down to 1 micron) so data is not compromised. The types of filter bodies and filter elements are based upon requirements for the particle size, stream loading factors, and the nature of the analyte gases to be analyzed. The objective of this section is to discuss the types of particulate control devices available and their application to ambient air monitoring at hazardous waste sites

b. Filter selection

(1) Coarse filtration. The objective of the coarse filter is to remove, at the front of the extractive system, large particles of 10 microns or greater. Three mechanisms applicable for removing large particles from a gas stream. They are:

- Passive filtration.
- Inertial separation.
- Inertial filtration.

In passive filtration, the particles are removed by impacting (filtering) on a surface area. The surface area can either be a flat porous material design or a cylindrical configuration design. In the flat porous material design,

air is pulled through the filter device, removing the particles of concern. The problem with this approach is that the filter material can become moist from atmospheric water aerosols and can interact with the analytes of concern, resulting in reduction or even elimination of the analytes of concern from the sample gas.



Figure 5-3. Example of heat-trace line layed above ground as part of perimeter volatile organic sampling system

Experience has shown that the cylindrical configuration is most applicable for extractive FFMSs. In this configuration, a sintered metal filter of large surface area, typically constructed of sintered 316 stainless steel, is placed at the inlet of the heated sample probe, as illustrated in Figures 5-4 and 5-5. Sintered filters normally remove all particles that are larger than 10 to 50 micrometers. Other types of material used in sintered filters are glass, ceramic, quartz, Carpenter 20 steel, and Hastelloy C steel. As illustrated in Figure 5-5, the porous medium is preceded by a funnel to prevent excessive moisture from entering the extractive system and is embedded in a heated compartment to prevent moisture from plugging the porous material. This

configuration allows minimum interference from particles building up on the sintered filter and from moisture interference. These filters should be maintained at or above the ambient temperature during sampling. As diagrammed in Figure 5-6 and pictured in Figure 5-7, the complete inlet system consists of an inlet funnel and a heated compartment containing a sintered stainless steel filter connected to the heated transfer line.



Figure 5-4. Example of sintered stainless steel inlet filter as part of a perimeter VOC FFMS

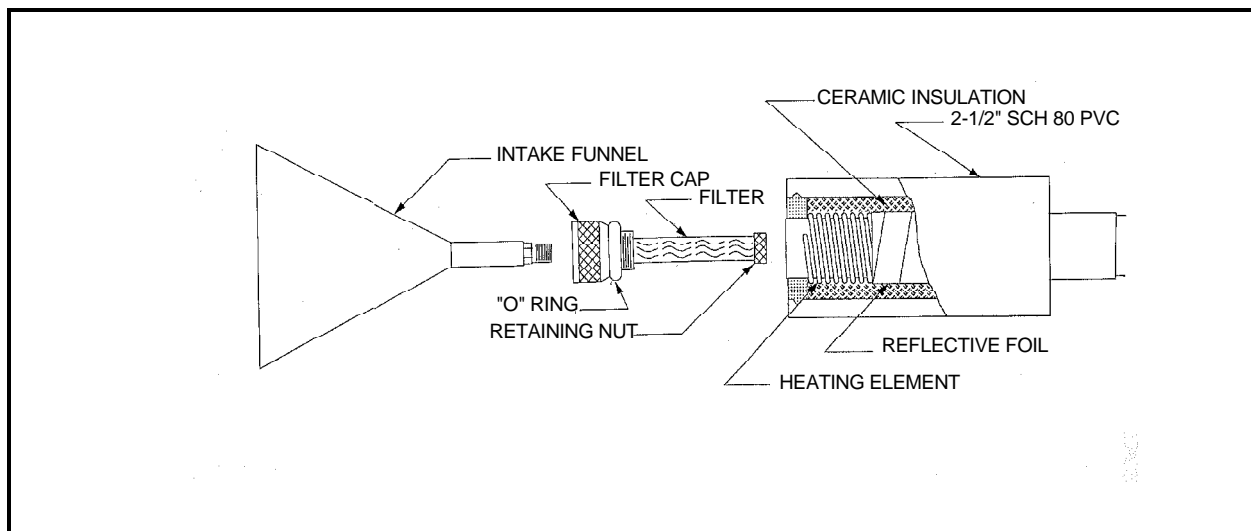


Figure 5-5. Example of probe inlet design with intake funnel and heated sintered stainless steel filter for particulate matter control

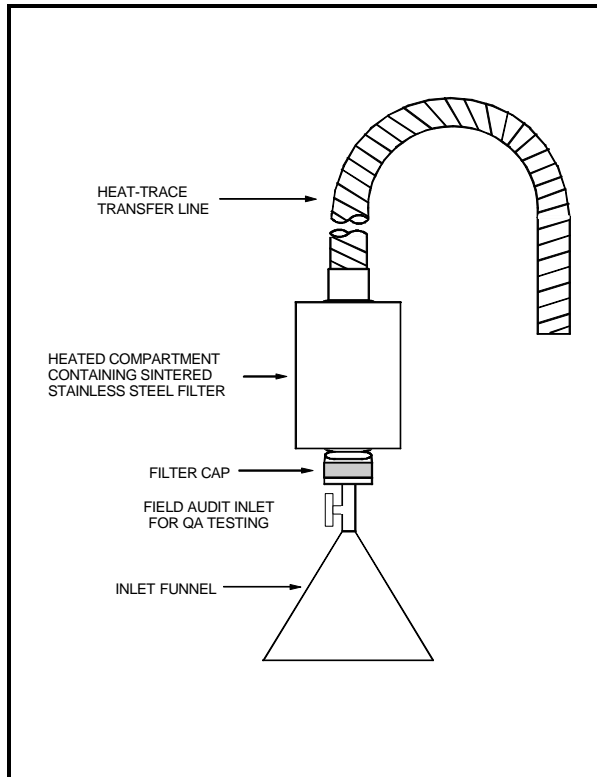


Figure 5-6. Composite of a FFMS inlet design for extracting samples for VOC analysis

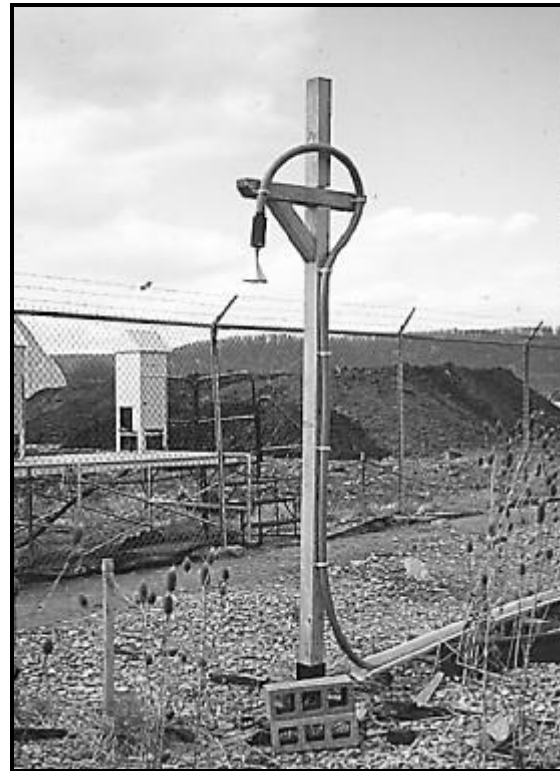


Figure 5-7. Example of field application of an inlet configuration for an extractive perimeter VOC FFMS

Large particles can also be removed by inertial separation. This type of coarse particulate removal can be accomplished by using a flow-through cyclone on the inlet of the sampling line. In the cyclone, the sample gas is introduced tangentially and exhausted through the bottom of the apparatus. The cyclonic flow causes the particles to be thrown against the walls of the device. The particulate-free gas stream is exhausted from the vortex inside the cyclone. Cyclones have a distinct particle cut size depending on the geometry, flow rate, and gas viscosity. The application of a cyclone as a coarse particle remover would be most applicable under ambient conditions of high particulate loading and in the presence of water droplets because cyclones do not plug easily and can be cleaned easily. The major drawback to the application of a cyclone in an ambient air monitoring program is that the cyclone is not readily heated, thus providing conditions where the sample gas is in contact with moisture droplets, allowing some form of scrubbing of target analytes to occur. The last mechanism for particulate removal is the inertial filtration. As illustrated in Figure 5-8, inertial filtration involves a flow-through tube filter where the sample gas is extracted from the main gas stream at a 90° angle. Within the probe, the high speed sample passes through a tubular (inertial) filter. A small portion of this sample is drawn radially through the porous filter wall at a velocity so low that the inertia of solid and liquid particles will be too high to curve through the wall of the filter. Consequently, the large ratio of axial to radial sample gas velocity in the tube filter prevents large particles from impinging on the filter pore structure. Small particles establish a dynamic membrane on or within the porous wall, and in equilibrium with very low drag forces, effectively prevents transmission of particulate contaminants much smaller than the filter pore size. The turbulent nature of particulate laden gas flowing through the filter tends to keep the filter clean by abrasion. The flow-through tube filter can be mounted either internally or externally to the sample inlet device. This approach has not been actively used at HTRW sites, but may have applicability in the future to the particulate management program for monitoring VOCs.

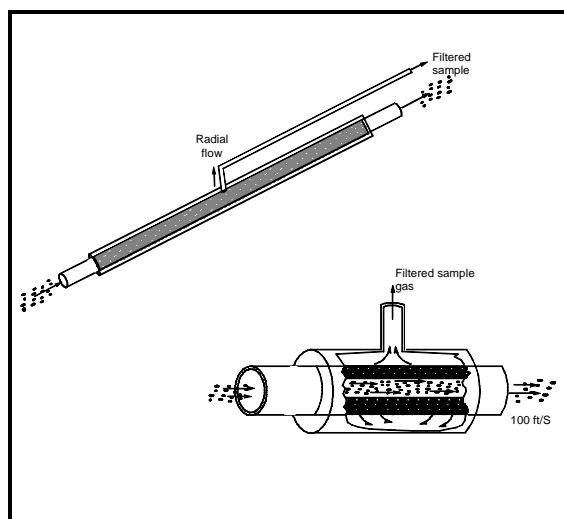


Figure 5-8. Example of an inertial filtration system as a particulate matter control device on an extractive VOC FFMS

(2) Fine filtration. Gases collected for FFMS systems will nearly always require complete removal of all particles larger than 1 micron prior to analysis. To reduce particles to this level, a secondary particulate control device is needed after the primary device. The secondary fine filtration device is usually located at the inlet to the analytical system in the Analytical Center. The fine filtration device needs to be a low-resistance, high-efficiency filter. Fine filters are divided into two categories: surface filters and depth filters. Surface filters remove particles from the gas stream using a porous matrix. These filters can remove particles smaller than the actual filter pore size as a result of particulate cake build-up and electrostatic forces acting to trap smaller particles without excessive resistance. Depth filters collect particulate matter within the bulk of the material. The depth filter may consist of loosely packed fibers or relatively large diameter granules. The spun glass filter or cellulose filter, when maintained, are reliable and efficiently remove particles as small as 0.5 microns. Spun glass, when packed to a density of 0.1 g/cm³ and a bed depth of at least 2 inches, can act as an inexpensive secondary filter for normal gas flow rates.

c. Inlet placement/probe height. In many cases, constraints on placing sampler inlet probes as part of the FFMS can be encountered because of wind flow obstructions caused by nearby buildings, trees, hills, or other obstacles. Other constraints might be related to security, the accessibility of electrical power, and the proximity to roadways or other pollution sources that might affect the representativeness of the sample for measuring the HTRW site's effect on air quality. Specific guidelines for probe siting for sampling representative conditions are:

- The most desirable height for sampler inlets is near the breathing zone (i.e., about 5 to 6 feet above ground). Practical factors such as high impermeable fences surrounding the HTRW site may sometimes require that sampling inlets be placed slightly higher (at least 1 meter above the top of the fence). As a compromise, the EPA requires the inlet to be between **2 to 15 meters** above ground.
- Inlet probes must be located away from obstacles and buildings so that the distance between the obstacles and the sampler inlet is at least twice the height that the obstacle extends above the probe inlet. **Airflow must be unrestricted in an arc of at least 270°** around the inlet, and the predominant wind direction for the season of greatest pollutant concentration potential must be included in the 270° arc.
- The **inlet probe and nearby roadways** must be sufficiently separated to avoid the effects of dust re-entrainment and vehicular emissions on measured air concentrations.
- The **inlet probe must not be impacted** by the location of collocated samplers or other obstacles.
- Stations that include particulate matter sampling systems collocated with the extractive gas inlet probe should not be located in an unpaved area unless there is vegetative ground cover year round so that the effect of locally re-entrained or fugitive dusts will be kept to a minimum.

Figure 5-9 illustrates a properly placed extractive gas inlet probe collocated with RMM time-integrated monitoring systems.



Figure 5-9. Example of properly placed extractive perimeter VOC inlet probe collocated with RMM time-integrated monitoring systems

5-4. Sample Transport Requirements

a. Sample transfer line. The main objective of the sample transfer line is to transport the sample gas from the extractive gas inlet probe assembly to the Analytical Center. In developing a sample transfer line, certain factors must be considered to ensure the transport of a sample from the inlet probe to the analytical system. These factors are:

- Sample integrity.
- Sample flow rate.
- Cost.
- Temperature

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The gas sample should be transported from the inlet probe to the rest of the transport system with minimum loss and interaction. There are several mechanisms by which interaction between sample gas and inlet probe can occur. They are:

- Reaction.
- Absorption.
- Adsorption.
- Dilution.

Gas phase reaction in transfer lines can occur by homogeneous gas phase reaction and by heterogeneous catalytic reaction. Materials of construction such as Teflon[®], stainless steel or glass are generally very poor catalysts and would not be expected to cause reactions. Absorption and adsorption by the walls of the transfer line would eventually reach equilibrium; consequently, the concentration of the constituent stream would not be changed. Studies have indicated that absorption and adsorption are negligible for stainless steel, Teflon[®], polypropylene, polyethylene, and Tygon[®].

The choice of proper material of construction is very important. Acceptable construction material must meet these important criteria:

- Material must have sufficient chemical resistance to withstand the corrosive constituents of the sample.
- Material must not exhibit excessive interaction (reaction, absorption, adsorption) with the sample gases.
- Material must be heated if moisture is not removed prior to sample transfer.

Consequently, the integrity of the sample greatly depends upon the material of construction of the transfer lines. For most air monitoring applications, construction materials focus on four types: Teflon[®] fluorocarbon resins, polyvinylchloride, stainless steels, and borosilicate glass. Each material is discussed below as to their applicability to a real-time volatile organic FFMS.

(1) Teflon[®] Fluorocarbon Resins. Teflon[®] resins are chemically inert to almost all industrial chemicals and solvents, which means that they can be in continuous contact with another substance with little detectable chemical reaction taking place. The inertness of Teflon[®] is due to (1) the very strong interatomic bonds between carbon and fluorine atoms; (2) the shielding of the carbon backbone of the polymer by fluorine atoms; and (3) the very high molecular weight (or long polymer chain length) compared to many other polymers. The two members of the family of Teflon[®] resin that are most commonly used in real-time FFMS are polytetrafluoroethylene (PTFE) and fluorinated ethylene-propylene copolymer (FEP).

(a) PTFE Teflon[®] resin is a white to translucent (opaque) solid polymer made by polymerizing the tetrafluoroethylene (C₂F₄) monomer. It is a highly crystalline polymer with high thermostability. Its heat resistance, chemical inertness, electrical insulation properties, and low co-efficient of friction in very wide temperature ranges make PTFE an outstanding plastic. When melted, PTFE does not flow like other

thermoplastics, and it must be shaped initially by techniques similar to powder metallurgy. PTFE shows excellent resistance to corrosive agents and dissolution by solvents, with a maximum continuous service temperature of 260°C (500°F). The PTFE Teflon® is the most common material used in transfer line for volatile organic extractive sampling systems.

(b) FEP Teflon® is a true thermoplastic that can be melted, extruded, and fabricated by conventional methods. FEP has a glossy surface and is transparent in thin sections, eventually becoming translucent as thickness increases. The FEP has a maximum continuous service temperature of 250°C (482°F).

(2) Polyvinylchloride (PVC). Polyvinylchloride is a linear chain compound produced by the polymerization of the vinyl chloride monomer. Rigid vinyl materials are primarily made of high molecular weight vinyl chloride polymers and are unmodified by plasticizers or similar materials; the addition of plasticizers will increase the flexibility of the PVC product. Rigid PVC has sufficient structural strength, impact resistance, and hardness to replace metals in many forms. PVC has relatively good resistance to chemical attack but is subject to degradation by ketones, aldehydes, amines, chlorinated alkanes, and alkenes in the pure solvent form, although the effect aqueous solutions of these solvents have on the integrity of PVC is not exactly known.

Flexible PVC (Tygon®) is quite different than rigid PVC due to the addition of more than 25 percent of various phthalates esters or plasticizers. These plasticizers give the PVC tube its flexibility, but are also the source of cross contamination when the tubing is used as part of a FFMS for organics. Phthalate esters can leach into the sample, where they are commonly detected by the analytical system in the Analytical Center.

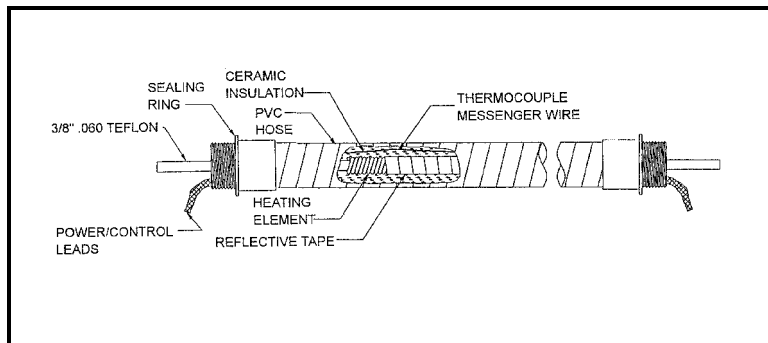
(3) Stainless steel. Stainless steel is one of a variety of steels alloyed with enough chromium to resist corrosion, oxidation, or rusting. There are two types of stainless steel that are generally used for FFMSs for organic sampling: Type 304 and Type 316. Both are heavier and more costly than polymers.

- **Type 304.** Type 304 stainless steel is a chromium-nickel steel with general purpose corrosion resistance. It is nonmagnetic in the annealed condition, but slightly magnetic when purchased. Type 304 stainless steel can be formed to most desired shapes with little difficulty.
- **Type 316.** Type 316 stainless steel is a non-hardenable chromium-nickel steel containing molybdenum, with superior corrosion and heat-resisting qualities. Type 316 has improved resistance to sulfur species and sulfuric acid and is commonly used for chemical handling equipment such as heat exchangers, condensers, evaporators, and piping.

While stainless steel can maintain the integrity of the gas sample, it has limited application as a transfer line as part of a FFMS around the perimeter of a HTRW site due to its rigid structure and limited tube lengths.

(4) Borosilicate Glass. Borosilicate glass is a soda-lime glass containing about five percent boric oxide, which lowers the viscosity of the silica without increasing its thermal expansion. Such glasses have a very low expansion coefficient and high softening point (about 593°C), with a continuous use temperature of 482°C. The tensile strength is about 10,000 psi. Pyrex® is a borosilicate glass that is commonly used for field application at HTRW sites.

In summary, Figure 5-10 illustrates a typical transfer line assembly containing sample line, heating elements and insulation.



For most applications, the placement of inlet sample probes as part of a volatile gas monitoring system around a HTRW site may require up to 1,000 feet per sample point extended from the Analytical Center, as illustrated in Figure 5-11:

- Inlet probe 1: 250 ft. from Analytical Center.
- Inlet probe 2: 800 ft. from Analytical Center.
- Inlet probe 3: 950 ft. from

Figure 5-10. Example of a complete heat-trace line assembly containing PTFE Teflon® as part of an extractive VOC FFMS

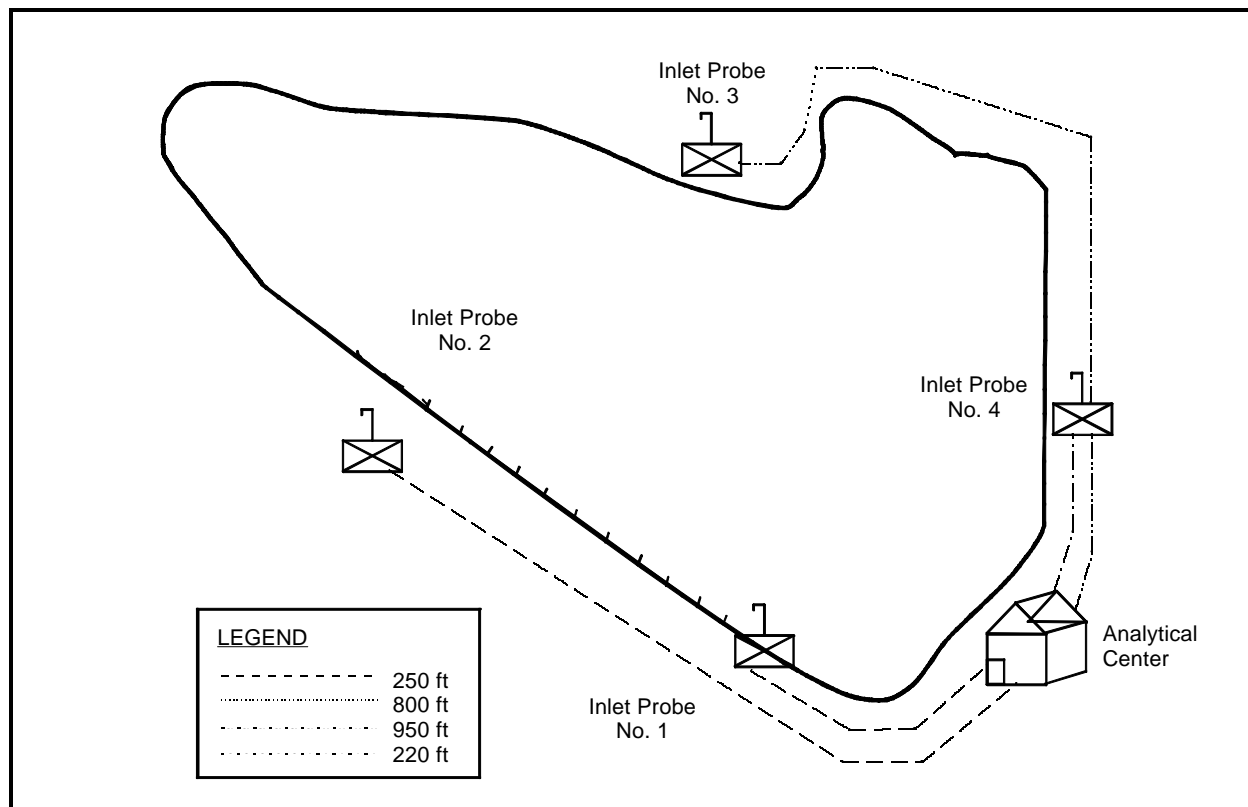


Figure 5-11. Example of up to 1,000 feet per sample point of heat-trace lines extends from Analytical Center to specific inlet probe locations around perimeter of HTRW site

Analytical Center.

- Inlet probe 4:220 ft. from Analytical Center

In developing an extractive FFMS, one has to determine whether heat-trace lines of single length would be applicable or to divide the lines into segments of nominal 200 feet to reach the inlet probe locations. There are several reasons for designing the system using nominal 200-foot segments. They are:

- The ability to provide heat to lines in excess of 500 feet is difficult due to the power requirements in maintaining temperature to a pre-set level.
- If a line fails due to line damage, electrical shorts etc., it is easier to replace a nominal 200-foot length than a 1,000-foot length of line.
- If a segment of line needs to be replaced, it is less costly and easier to work with a nominal 200-foot segment.

Consequently, the inlet probes may be joined with the Analytical Center, using heat-trace lines constructed of nominal 200-foot segments, with junction boxes (J-box), as illustrated in Figure 5-12.

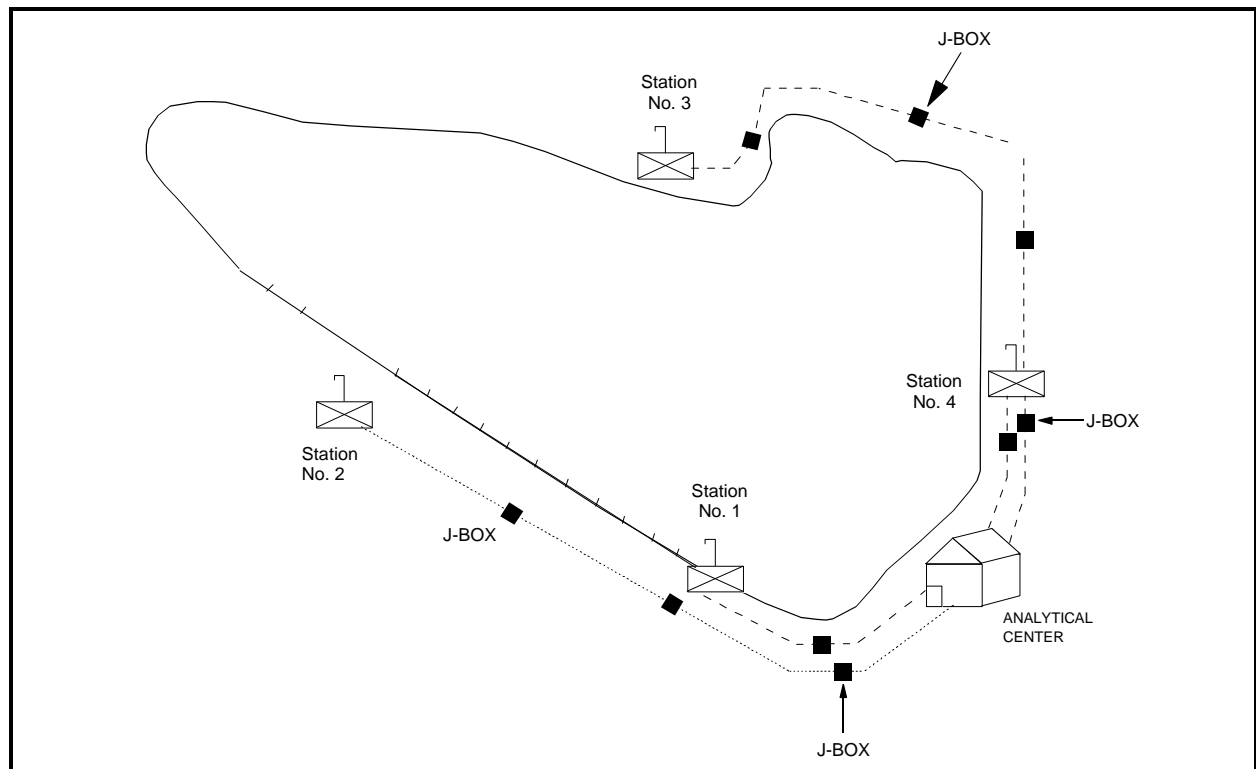


Figure 5-12. Example of nominal 200-foot heat-trace line segments connected to Analytical Center using J-Boxes around perimeter of HTRW site

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The components of a typical J-box are illustrated in Figure 5-13. The J-box allows the union of several 200-foot PTFE Teflon® segments using stainless steel fittings. Each of the sample lines is connected to its predecessor via an electrical junction box, as illustrated in Figure 5-14. The lines feed into either side of the enclosure where they are joined with a stainless steel compression fitting. To minimize any cold spots in the J-Box, the heated portion of the sample line actually enters the box to the tube union that is covered with a high-efficiency strip of insulation to minimize heat loss. Terminal blocks to provide power for the adjacent sections are also contained in the enclosure, as well as thermocouple connectors and mounting to monitor each section during regular audits of the system.

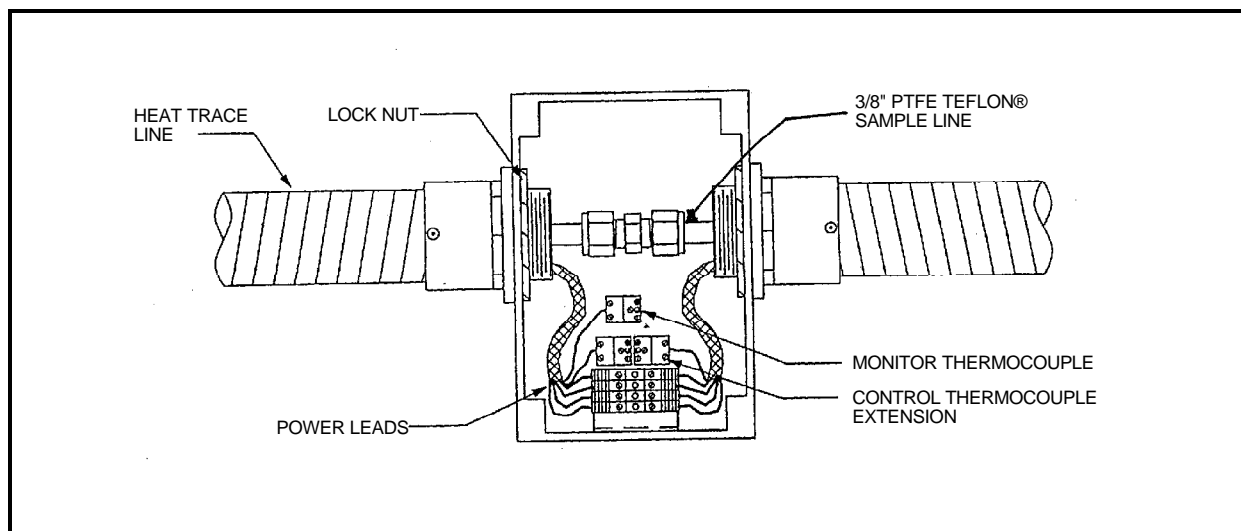


Figure 5-13. Example of components of a typical J-Box used to connect nominal 200 foot lengths of heat-trace lines

All heat-trace lines should be wrapped in a very uniform fashion to ensure a consistent temperature across the entire device. Multiple heating elements are usually cut to a precise resistance and wired in a parallel circuit over the entire unit. Current draw per element is kept relatively low to extend service life. High efficiency insulation applied in a consistent manner also increases temperature stability and product life. In addition, foil is applied over the heating elements to reflect heat back to the sample line core. This design has the effect of increasing the lines' efficiency and temperature stability. The ends of the heated lines should be sealed in a high-temperature epoxy potting compound to protect both the device and its user.

All heat-trace lines should be sleeved in a heavy-duty, flexible vinyl hose suited for direct burial applications. The seals should be rated for outdoor use. Due to the length requirements for the heat-trace lines, they should be designed for 480 VAC, three-phase power, which allows the user to keep the current draw circuit leg down to a manageable level and extends product life and reliability.



Figure 5-14. Actual on-site connection of two heat-trace lines using a J-box as part of a FFMS

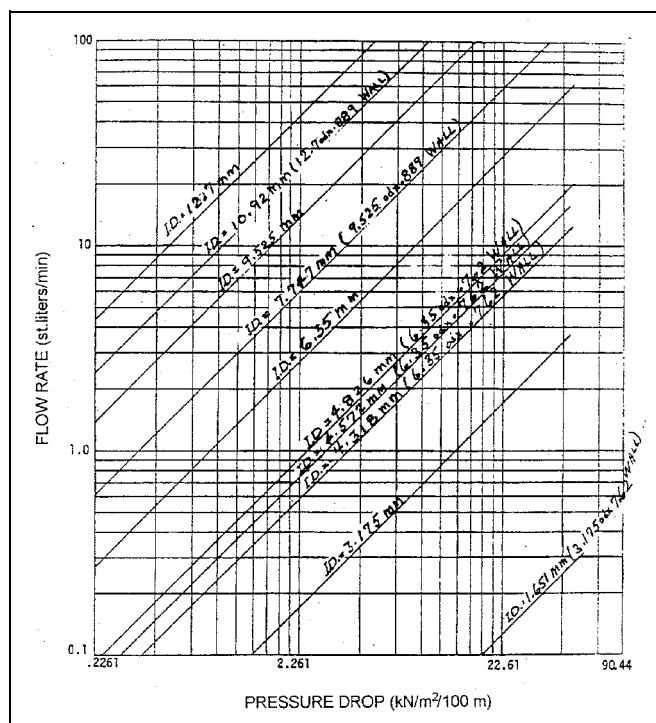


Figure 5-15. Example of flow rates vs. pressure drop for various sample lines sizes

Control for the heat-trace sample line are provided by panel mount temperature controllers. Each controller reads the temperature of the line at the beginning of the sample path. That signal is conveyed through the adjoining 200-ft. sections by means of a thermocouple messenger wire. The uniform watt-density along the entire sample line run allows for precise control of the heated sections with minimal temperature variance.

b. Sample flow rate requirements. The sample line must be large enough so that a pump can handle the pressure drop, yet small

enough so the response time is not excessive. Flow rates as a function of pressure drop are shown for various line sizes in Figure 5-15.

Studies have shown that for a typical flow rate of two liters per minute (ℓ/min), 6.35 mm I.D. tubing will give only a pressure drop of between 1 and 3 mm Hg per 100 ft. of tubing. This reading is not an excessive pressure drop for a real-time volatile FFMS.

The lag time (t) for a sample line volume (V) may be calculated according to the following equation:

$$t = \frac{V}{F}$$

where:

- t = Lag time (sec);
- V = sample line volume (ft³); and
- F = Flow rate (ft³/sec).

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As an example, for a tube with an I.D. of 6.35 mm and 100 ft. from the sample inlet probe to the Analytical Center, the lag time for a flow rate of 2 l/min is calculated as follows:

- 1st = Convert diameter of tube from mm to ft.:

$$(6.35 \text{ mm})(32.808 \times 10^{-4} \text{ ft/mm}) = 0.0208 \text{ ft.}$$

- 2nd = Calculate area of tube:

$$A = \pi r^2 = \pi \left(\frac{D}{2} \right)^2 = \frac{\pi D^2}{4} = \frac{\pi (0.0208 \text{ ft})^2}{4} = 0.0003398 \text{ ft.}^2$$

- 3rd = Calculate volume of sampling line:

$$V = (A)(L) = (0.0003398 \text{ ft}^2)(100 \text{ ft}) = 0.03398 \text{ ft}^3$$

- 4th = Convert flow rate from L/min to ft³/sec:

$$(2 \text{ l/min})(5.886 \times 10^{-4} \frac{\text{ft}^3 \cdot \text{min}}{\text{L} \cdot \text{sec}}) = 0.001177 \text{ ft}^3/\text{sec}$$

- 5th = Calculate lag time using volume and flow rate:

Table 5-2
Example of Sampling Line Lag Time For Various Dimensions

Tubing Size (mm)	Lag time per (30.48 m) length (seconds)	
	1 liter per min	2 liter per min
1.651 (3.175 o.d. x 0.762 wall)	3.9	2
3.175 (3.175 i.d.)	14	7.2
4.318 (6.35 o.d. x 1.016 wall)	27	13
4.572 (6.35 o.d. x 0.889 wall)	30	15
4.826 (6.35 o.d. x 0.762 wall)	33	17
6.35 (6.35 i.d.)	58	29
7.747 (9.525 o.d. x 0.889 wall)	86	43
9.525 (9.525 i.d.)	130	65
10.92 (12.70 o.d. x 0.889 wall)	170	86
12.70 (12.70 o.d.)	230	116

$$\frac{V}{F} = \frac{(0.03398 \text{ ft}^3)}{(0.001177 \text{ ft}^3/\text{sec})} = 29.0 \text{ sec}$$

For the above example, the lag time calculation would be 29 seconds for a 100-foot heat-trace lines segment. This lag time is well within the EPA guideline of 15 minutes. Table 5-2 displays lag times for 100 feet of sample line with various inside diameters for flow rates of 1 and 2 standard liters per minute (L/min).

(1) Heating of sample inlet/ transfer line. Ambient air samples usually contain a measurable percent of water that, when cooled, can condense out in the sample line. This characteristic can present a

significant problem in an ambient air program because many organics are soluble in water. In addition, very few analytical systems are insensitive to water vapor. For those systems, the sample gas is maintained above the dew point by heating the sample inlet and filter, transfer line, and pump before the moisture removal system.

When the FFMS components of interest are easily condensed or water soluble, it is necessary to avoid water condensation or removal from the sample. There are two methods for keeping water in the vapor phase in a sample gas stream extracted at a HTRW site: heating and pressure reduction. Heating a gas stream above the dew point will keep water in the vapor phases if the total pressure is near atmospheric. By dropping the pressure of the gas stream, a lower condensation temperature can be realized. Figure 5-16 shows the relationship for temperature required to keep water in the vapor phase as a function of pressure. The application of this method

will not occur at room temperature. Once the appropriate pressure is achieved, no further heating would be required.

Table 5-3 presents the maximum temperature of various plastic materials. Depending upon the condition and extraction locations, all materials are candidates for transfer material. The less heat resistant plastics (polypropylene and polyethylene) cannot be used as efficiently when heating the sample transfer line to 212°F. For most FFMS sample transfer applications, PTFE Teflon® will be the best candidate as the material of construction for a heated transfer line.

(2) Cost. Costs are very important when considering putting together a real-time FFMS.

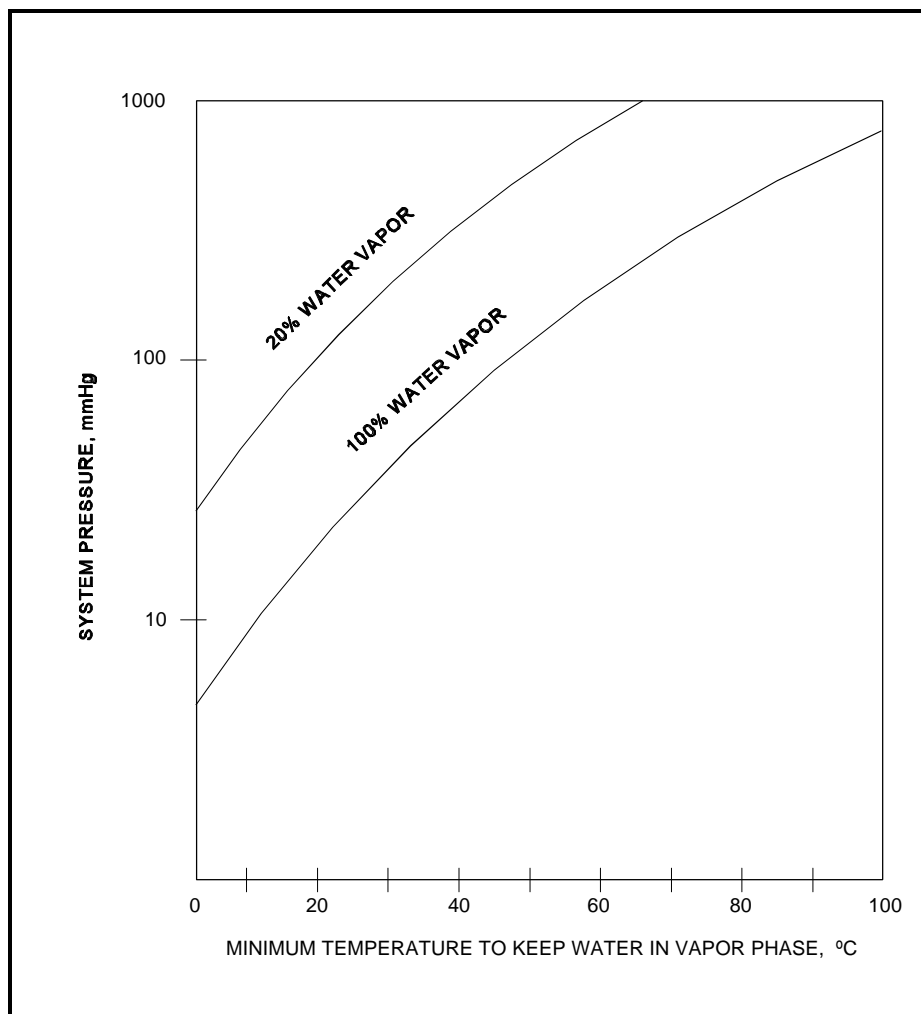


Figure 5-16. Example of temperature vs. system pressure to maintain water in the vapor state

Table 5-3
Maximum Continuous Operating Temperatures for Heat Trace Lines Materials of Construction

Material	Maximum Temp. (°C)
Plastics	
Teflon	250
Viton	150
Polyethylene*	80-125.6
Polypropylene	110
PVC	110
Tygon*	60-82.2
Stainless Steels	
Carpenter 20	871
316 SS	870
304 SS	788
Nickel Alloys	
Hastelloy C-276	1,038
Inconel 625	980
Incoloy 800	760
Incoloy 825	704
Non metallics	
Aluminum silicate	1,540
Quartz glass (fused silica)	900-1,200*
Ceramic	1,094-1,538*
Zirconium oxide	2,204
Pure Element	
Titanium	800-1,000

*Depending on type used.

Table 5-4 illustrates the cost of various heat-trace line materials per 100 feet of construction.

(3) Placement of heat trace lines. Once all variables for the construction and design of the heat-trace lines have been selected, consideration must be given to locating the line around the perimeter of the HTRW site. As illustrated as an example in Figure 5-11, heat-trace lines may have to be extended up to 1,000 feet around the HTRW site. Placement of heat-trace lines may require laying the lines across access points to the interior of the

HTRW site. Passenger vehicles and heavy-duty trucks will need access to the site. Two options are available for placement of heat-trace lines around a HTRW site:

- Aerial placement.
- Burial option.

Aerial placement depends on the availability of support poles (i.e., telephone poles) around the HTRW site. A limitation of this approach is that the lines are heavy and during inclement weather may strain the internal components of the lines due to ice formation. This application has not been routinely used at HTRW sites.

Table 5-4
Example Cost of Various Sample Line Materials Based on 100 ft of 6.35 mm OD Tubing

Material	Wall Thickness	List Price per 30.48 m, \$
Heat Traced Teflon®	0.889	2,500
Heat Traced 316 Stainless Steel	1.016	3,250
Carpenter 20 Stainless Steel	0.889 welding	4,500
Heat Traced 304 Stainless Steel	0.889 seamless	3,000
Viton® Heat Trace	1.575	1,450
Tygon® Heat Trace	1.575	1,560
Aluminum	0.889	1,100
Glass	8mm CD x 6mm ID	733
Nylon®	0.762	440
Polypropylene	0.787	431
Polyethylene	1.016	370

The most common option is placing the lines on the ground and burying the lines in areas where access is needed to the site. When the lines are above ground, the lines should be enclosed in a suitable conduit to protect from accidental damage, as illustrated in Figure 5-17. In this illustration, the 4-inch heat-trace line is encapsulated in scheduled 80 PVC conduit/pipe for protection. Other materials of construction (i.e., cast iron, steel etc.) can also be used to protect the lines. The heat-trace lines should then be placed in a shallow trench, as illustrated in Figure 5-18, for further protection.

For those areas where access to the interior of the site is required, the encapsulated heat-trace lines must be buried to protect them from damage from on-site vehicles. These lines should be buried below the "frost line" for that region or at a minimum of 2 feet. After burial, 1-in. thick steel plates should be placed over the area of the buried



Figure 5-17. Example of encapsulated heat-trace line in PVC conduit around the perimeter of a HTRW site



Figure 5-18. Example of encapsulated above-surface heat-trace lines entering sub-surface location around the perimeter of a HTRW site

encapsulated heat-trace lines to provide additional protection from heavy truck traffic. These would be the only areas where truck traffic would be allowed to enter or exit from the site. Figure 5-18 illustrates encapsulated surface heat-trace line from entering subsurface location at the entrance of a HTRW site.

c. Sample pumps

The main purpose of a pump in a perimeter air monitoring system is to transfer the gas stream from one location to another. This process may be done either by positioning the pump upstream of the analytical system (positive pressure) or downstream of the analytical system (negative pressure). The pump location will determine the characteristics of that pump.

Pumps can be divided into three broad categories:

- Positive displacement pumps.
- Centrifugal pumps.
- Eductor.

(1) Positive displacement pumps. Positive displacement pumps can be characterized by a linear relationship between the change in capacity (ΔQ) of the pump and the pressure drop (ΔP) across the pump. In essence, as the volumetric flow rate changes, a concurrent and direct change occurs in the pressure drop across the pump, which becomes a constant.

The name positive displacement pump arises from the fact that air is displaced by the movement of the inner components of the pump. The mechanism by which the moving part displaces the air determines the principle of operation. For example, pumps containing fixed casings with movable pistons are called reciprocating pumps, part of the positive displacement classification. Pumps that utilize a

gear or lobe to move air are called rotary pumps. Table 5-5 illustrates the two subdivisions of the positive displacement pump.

The piston pump is characterized by the movement of a piston in a fixed volume. The piston displaces the air occupying the same space on the discharge side. Likewise, the air displaces the piston on the suction side.

Table 5-5
Subdivisions of Positive Displacement Pumps

Principle of Operation	Type of Pump
Reciprocating	piston plunger diaphragm
Rotary (not discussed in this manual)	gear lobe vane screw rotary plunger

The diaphragm pump is by far the most common pump used in perimeter air monitoring sampling systems. The operation is very similar to the piston pump. Once again, air is displaced by movement of a diaphragm, the outer edges of which are bolted to a flange on the pump casing. The diaphragm may be made of metal, Teflon®, or neospore. The most important characteristic of the diaphragm material is its flexibility and resistance to reaction with the air being moved. As the diaphragm moves up, air flows into the pump via a suction valve. As the diaphragm moves down, air is funneled through a discharge valve. Consequently, the gas moves into and out of the pump. Figure 5-19 illustrates the operation of a typical diaphragm pump, the most commonly used pump as part of a HTRW FFMS.

(2) Centrifugal pump. Different from the positive displacement pumps, centrifugal pumps employ centrifugal force to move air. The movement of an impeller rotating in a volute ("snail's shell") casing causes a differential pressure, thus pulling air into the center of the shaft. The air is then picked up by the rotating vanes and accelerated. It is then discharged by way of the discharge nozzle.

(3) Air driven eductor. Air driven eductors are becoming more prevalent as the pump of choice for real-time monitoring systems. Present application of the eductor has been both as the primary or secondary air mover. In the primary configuration, the eductor acts according to the jet principle, as depicted in Figure 5-20.

At the nozzle, the high pressure driving force is converted into a high velocity stream. The passage of the high velocity stream through the suction chamber creates a decreased pressure (vacuum),

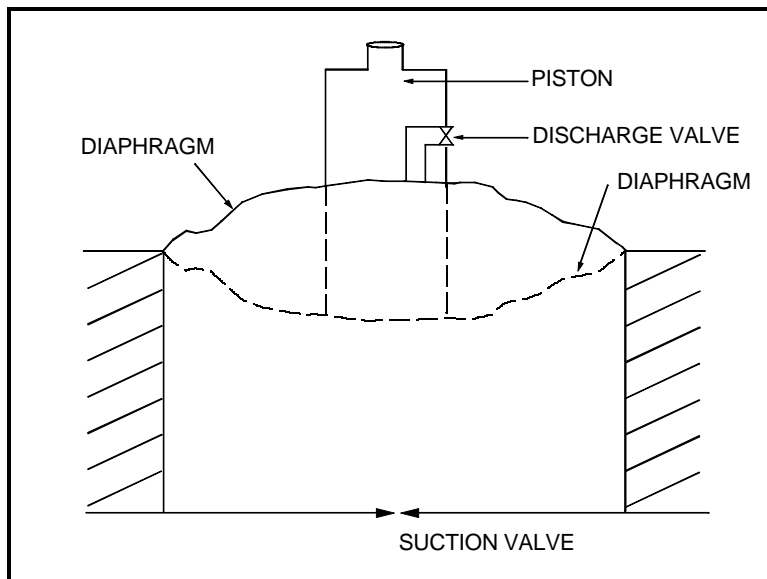


Figure 5-19. Example of the operation of a diaphragm pump used as part of a FFMS at a HTRW site

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thus drawing air into the chamber. The incoming air is mixed with the high velocity gas mixture and is ejected against a moderate pressure through a diffuser. In this configuration, the high pressure gas stream pulls the ambient air into the eductor area. A second pump, located downstream of the conditioning system, pulls the needed gas sample off of the air inlet position before the eductor or nozzle.

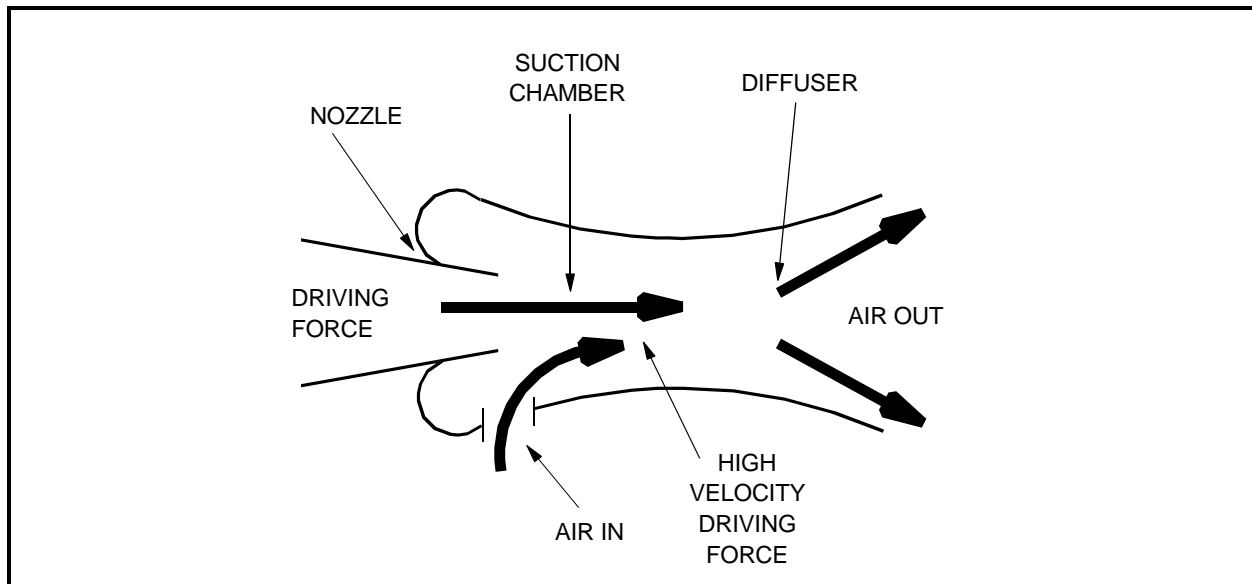


Figure 5-20. Example of an air driven eductor used as part of a FFMS at a HTRW site

As evidenced by the above discussion there are many choices available in selecting a pump. A comparison of some of the advantages and disadvantages of pumps used in HTRW FFMSs are given in Table 5-6.

Table 5-6
Example of Advantages/Disadvantages of Air Moving Systems

Pump type	Advantages	Disadvantages
Piston pump (reciprocating)	<ol style="list-style-type: none"> 1. Can operate at high suction pressure 2. Can be metered 	<ol style="list-style-type: none"> 1. Small capacity 2. Seal required between piston and piston chamber 3. Working parts such as check valves and piston rings may cause difficulties 4. Pulsating flow 5. Moderate maintenance
Diaphragm pump (reciprocating)	<ol style="list-style-type: none"> 1. Wide range of capacities 2. No seal required 3. Good in continuous operation 	<ol style="list-style-type: none"> 1. Limited materials of construction 2. Operation at limited suction pressures 3. Pulsating flow 4. Periodic diaphragm replacement 5. Moderate maintenance
Centrifugal pump	<ol style="list-style-type: none"> 1. Large Range of capacities 2. No close clearance 3. Can obtain high suction heads by multistages 4. Light maintenance 	<ol style="list-style-type: none"> 1. No small capacities 2. Turbulence 3. Operational noise
Eductors	<ol style="list-style-type: none"> 1. No moving parts 2. Limited hardware in contact with gas stream 	<ol style="list-style-type: none"> 1. Requires unrestricted flow 2. Plugging in exit port of eductor 3. May require steam to help dislodge particles

5-5. Sample Conditioning System

As with most analytical systems, sample conditioning involving water management is an important component of the extractive system to maintain the integrity of the sample. Most analytical techniques are sensitive to water vapor, interfering with the detection and quantification of the analytes. In addition, condensation within the sample extraction system can compromise the sample by scrubbing out the analyte of concern. Therefore, the design of an extractive system must address the water management issue. There are a variety of techniques available for water management, including:

- Condensation.
- Permeation dryers.
- Dessicant techniques.
- Sample temperature.

a. Condensation. Condensation is the most common form of water management for gas streams containing a large percent of water (i.e., incinerator gases, etc.). In operation, a condenser is used to cool the gas stream below the dew point of water to condense the water at a centralized location. Condensers can be cooled either by circulating fluid outside the condensing surfaces or by circulating air. Refrigerated condensers are most commonly used for cooling sample gas streams. A typical refrigerated condenser contains a primary and

secondary configuration where the moisture level is reduced to less than 3 percent in the primary condenser and less than 1 percent in the secondary condenser. Because the first condenser is less than atmospheric, the efficiency is not as good as the secondary condenser, which is greater than atmospheric. The secondary condenser is more efficient because the increase pressure enhances the condensation process by reducing the vapor pressure of moisture and increasing the residence time in the coil. Sample gas exiting the condenser typically contains moisture levels approaching 0 percent.

While the condenser is the most effective moisture control technique, its major drawback is that the gas stream is in contact with the condensed water, which may lead to sample component loss, especially for polar compounds. Because a liquid is condensed from the gas stream, an automatic drain valve should be incorporated into the system to help eliminate gas adsorption in the condensate.

b. Permeation dryers. Permeation dryers have become increasingly utilized as part of an FFMS moisture handling component. The permeation dryer, which utilizes a non-contact technique, is composed of semi-permeable membrane lines housed in a hollow stainless steel tube, as illustrated in Figure 5-21. The dryer is a bundle of membrane tubes with a common header in a shell and tube configuration. This type of dryer is termed a tube-and-shell type.

In operation, the moist ambient gas stream must enter the dryer at positive pressure through the tube side, as illustrated in Figure 5-21. Counter current to this flow is a low pressure dry purge gas supplied to the shell side of the tube-and-shell. This differential pressure is used along the tubes, which are made of semi-permeable membrane. This unique membrane allows water vapor molecules to permeate through its skin, retaining the gas constituents. The water molecules move from the high pressure gas stream to the low pressure purge gas stream through the semi-permeable tube membranes. The now water-laden purge gas stream is exited out the side of the dryer. The water-free gas stream exits out of the high pressure outlet side of the dryer. The efficiency of the dryer at constant temperature and humidity is based on the amount of tubing in the shell, and permeation drying can be accomplished by heating the inlet to the drier so the entering gas stream is above the dew point of all constituents. In addition, periodic blow-back of the system helps to remove embedded particles in the tube membranes thus increasing the efficiency and life of the water management system.

The gas stream must enter the device above its dew point to allow permeation to occur; liquid water plugs the system, decreasing its efficiency. Likewise, particles can adversely affect the operation of the dryer.

Advantages for using a permeation dryer over a condensation technique are:

- Non-contact technique so less acceptable to condensation.
- Less possibility sample component loss due to condensation.
- No condensate trap required.
- Competitively priced.

Disadvantages for using a permeation dryer are:

- Plugging of the membrane tubes due to particles.
- Required hardware associated with the low pressure dry purge gas inlet.
- Loss of polar components.
- Location limitation of dryer application.

5-6. Routine Maintenance and Corrective Action Requirements

a. Routine maintenance. Quality of monitoring data is directly linked to the performance of the real-time FFMS at an HTRW site. Routine preventative maintenance of instrumentation and equipment is essential to ensure the performance of the real-time system. Maintenance procedures should be developed for any real-time system that are specific to the individual instrument and other equipment components employed. At a minimum, all real-time system equipment, instrumentation, tools, and other items requiring routine maintenance should be serviced in accordance with manufacturer's specifications or recommendations. Typical routine, preventative maintenance activities associated with the various components of a typical collection system are outlined in Table 5-7. Manufacturer's guidelines provided for specific equipment or instrumentation deployed and/or actual field experience with the equipment or instrumentation may dictate additions to the activities listed.

All routine maintenance activities should be documented on a form such as the example provided as Figure 5-22. Such records must be traceable to the specific equipment item. These records will be subject to audit by project quality assurance personnel. Preventative maintenance and corrective action activities should also be documented in the instrument log book, site log books, and daily reports (i.e., DCQCR).

b. Corrective action requirements. In the event that extractive system operating conditions are identified that adversely affect data quality to any significant degree, the cause(s) should be determined and corrective actions taken to prevent recurrence. These actions may involve maintenance, repairs, or modifications to

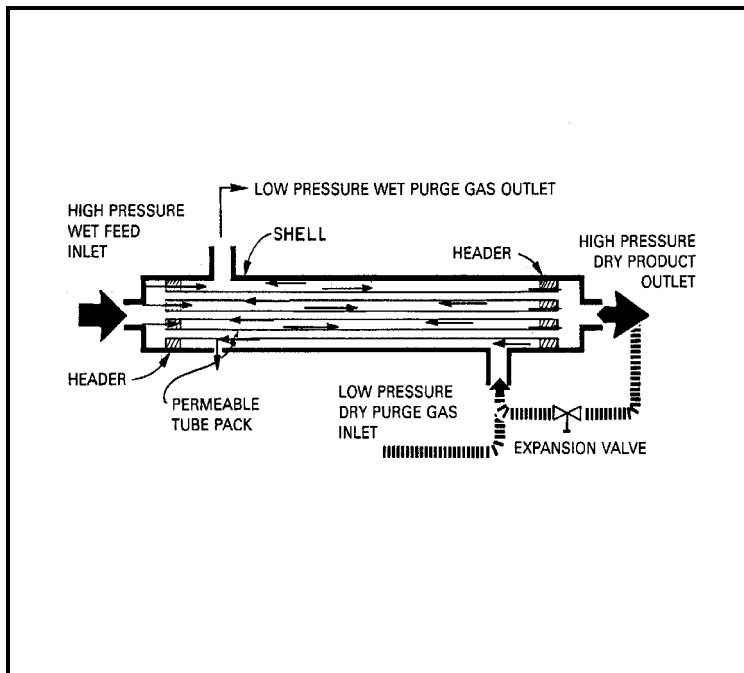


Figure 5-21. Example of a perma-pure dryer used as part of a FFMS at a HTRW site

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instrumentation or equipment and/or modification of operating procedures. Corrective actions may be initiated:

- When predetermined acceptance standards (objectives for precision, accuracy, and completeness) are not attained.
- When data compiled are determined to be faulty.
- When quality assurance requirements have not been achieved.
- As a result of routine preventive maintenance activities.
- As a result of system and performance audit reports.
- As a result of a management assessment.
- As a result of laboratory/inter-laboratory comparison studies.

Table 5-7
Example of Routine Maintenance and Corrective Action for a Sample Collective System

Instrument	Type of performance	Frequency	Specifications
• Analytical system	• Calibration -- Single point *NMOC *Speciated organics	• Daily	• $\pm 10\%$ of RT and peak voltage • Recovery 75-125%
	• -- Multi-point • Operating flows and oven temp.	• Weekly • Daily	• $\pm 25\%$ audit accuracy • $\pm 25\%$ of set-points
• Sample Transfer System (Heat-trace lines)	• Chemical checks of heat-trace lines -- NMOC -- Single point speciated organics	• Weekly	• 60-140% recovery
	• Leak check	• Weekly	• $\pm 2"$ Hg vacuum for 15 minutes
	• Flow check	• Weekly	• $\pm 10\%$ of initial flow
• Meteorological system	• Wind direction • Wind speed • Temperature (T_1/T_2)	• Quarterly	• Wind direction: 5° • Wind speed: ± 0.2 m/s • Temperature: $\pm 0.5^\circ\text{C}$
• Data acquisition system	• Electronic voltage checks and calculations	• Quarterly	• $\pm 10\%$ of set-points

<p>PERIMETER AIR MONITORING SYSTEM EQUIPMENT MAINTENANCE/REPAIR REPORT</p>	
<p>Instrument/Equipment Item: _____ Date: _____</p>	
<p>Description of Problem: _____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p>	
<p>Action(s) Taken: _____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p>	
<p>Date/Time Item Returned to Service: _____</p>	<p>Initials: _____</p>

Figure 5-22. Example of equipment maintenance/repair report as part of a FFMS program

- When samples and test results cannot be traced with certainty.
- When designated approvals have been circumvented.
- When other operating procedures are determined to be faulty.

Corrective action procedures should be developed as part of the Project Quality Assurance Plan, the Perimeter Air Sampling Plan (PASP), and the various SOPs. In the case of instrumentation and equipment, manufacturer's recommendations should be the starting point for all equipment diagnostics, maintenance, and repairs. Corrective action activities recommended as a result of system or performance audits will be recorded in the relevant audit report. In addition, all corrective action activities should also be documented on a form such as the example provided as Figure 5-23. These records must also be traceable to the specific equipment or procedural item. Corrective action activities should also be documented in the instrument log book and daily reports.

5-7. Time-Integrated and Real-Time PM_{10} Monitoring Requirements for Collection System

PM_{10} monitoring at the perimeter of a HTRW site is often required and can be integrated within the FFMS by locating the PM_{10} monitors next to designated extractive gas inlet probe. From a regulatory standpoint, sampling options for TSP and PM_{10} compliance monitoring collocated with sample inlet probes for FFMS volatile organics fall into two categories as discussed in Chapter 4: reference methods and equivalent methods. Reference methods are those sampling procedures that were initially established by EPA for determining average TSP and PM_{10} concentrations during a fixed time period. Hence, these methods are also termed time-integrated. These are by far the most commonly used TSP and PM_{10} measurement methods. Alternatively, EPA has more recently designated certain continuous reading instruments as equivalent methods for measuring ambient air concentrations of TSP and PM_{10} at or near real-time. Real-time measurements are useful when parameters such as the diurnal variation in concentration or changes in concentration associated with specific site activities of interest. Figure 5-24 illustrates a collocated time-integrated TSP system with sample inlet probe for a FFMS for volatile organics.

a. Description of sampling systems

(1) Reference methods. The reference or time-integrated method for TSP is codified at 40 CFR 50, Appendix B. This method uses a high-volume (hi-vol) sampler to collect particles with aerodynamic diameters of approximately 100 microns (μ m) or less. The essential features of a typical hi-vol sampler are shown in Figure 5-25. It is a compact unit consisting of a protective housing; a high-speed, high-volume electric blower; a filter holder capable of supporting an 8 by 10-inch filter; and a flow-controller and blower assembly capable of maintaining the air-flow rate through the instrument at 40 to 60 cubic feet per minute (ft^3/min) throughout the sampling period. The hi-vol sampler design causes the TSP to be deposited uniformly across the surface of the fixed filter. The TSP hi-vol can be used to determine the average ambient TSP concentration over the sampling period, and the collected material subsequently can be analyzed to determine the identity and quantity of inorganic metals present in the TSP. As discussed in Chapter 4, the TSP methodology has been included as part of Chapter 2, Method IO-2.1, "Sampling of Ambient Air for Suspended Particulate Matter (SPM) Using High Volume (HV) Sampler" of EPA's *Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air*.

PERIMETER AIR MONITORING SYSTEM
CORRECTIVE ACTION REPORT

Date: _____

Time: _____

Description of Problem: _____

Recommended Corrective Action: _____

Action(s) Taken: _____

Date/Time Action Implemented: _____

Initials: _____

Figure 5-23. Example of a corrective action report as part of a FFMS program



Figure 5-24. Example of application of a RMM for time-integrated TSP monitoring collocated with sample inlet probe for a FFMS for volatile organics around the perimeter of a HTRW site

The reference method for PM_{10} is codified in 40 CFR 50, Appendix J. Two technologies have qualified as meeting the sampling requirements of the reference method for PM_{10} : a hi-vol with a 10 m inlet and a dichotomous sampler. The PM_{10} hi-vol is identical to the TSP hi-vol except that it is equipped with a sampling inlet that directs only particles with aerodynamic diameter of 10 m or less to the filter.

A dichotomous sampler, shown in Figure 5-26, collects only PM_{10} . The sample is further split into fractions above and below 2.5 m at the sample inlet. Both the hi-vol and dichotomous samplers deposit the particulate matter uniformly across the surface of fixed filters. Both can be used to determine average ambient PM_{10} concentration over the sampling period, and the collected material from both subsequently can be analyzed for inorganic metals and other materials present.

Similar to the TSP methodology, Chapter 2, Method IO-2.2, "Sampling for Suspended Particulate Matter in Ambient Air Using a Dichotomous Sampler," has been included as part of EPA's *Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air*.

Both the hi-vol or dichotomous sampler can be equipped with either of two basic types of flow control systems, a mass-flow-control (MFC) system and a volumetric-flow-control (VFC) system. The calibration and standard operating procedures differ considerably between these two types of flow-control systems, and therefore operational procedures are control-system-specific.

The flow rate in an MFC system is actively sensed and controlled at a predetermined set point. Air is pulled through the filter into the intake of the blower and subsequently exits the sampler through an exit orifice, which facilitates measurement of the flow with a manometer or pressure recorder. The flow rate is controlled by an electronic mass-flow controller, which uses a flow sensor installed below the filter holder to monitor the mass flow rate and related electronic circuitry to control the speed of the motor accordingly. The controlled flow rate can be changed by an adjustment knob on the flow controller.

A VFC system maintains a constant volumetric flow rate through the inlet, rather than a constant mass flow rate as in the MFC system. In a popular commercial VFC system, a choked-flow venturi is employed such that the air attains sonic velocity in the throat of the device. In this "choked" mode, the flow rate is unaffected by downstream conditions, such as motor speed or exit pressure, and is a predictable function of upstream conditions, such as the ambient pressure and temperature. Thus, the volumetric flow is controlled without any moving parts or electronic components. In this type of flow control system, no means is provided for adjusting the controlled flow rate.

Once the filtration collection technique is selected (i.e., Hi-Vol, Partisol®, PM₁₀), consideration must be given to the type of filter to use in the collection device. Several air sampling filter types are available and the specific filter used depends upon the desired physical and chemical characteristics of the filter and the analytical methods to be used. No single filter medium is appropriate for all desired analyses. Particle sampling filters consist of a tightly woven fiber mat or plastic membrane penetrated by microscopic pores. Several characteristics are important in selecting a filter media, including:

- Particle sampling efficiency.
- Mechanical stability.

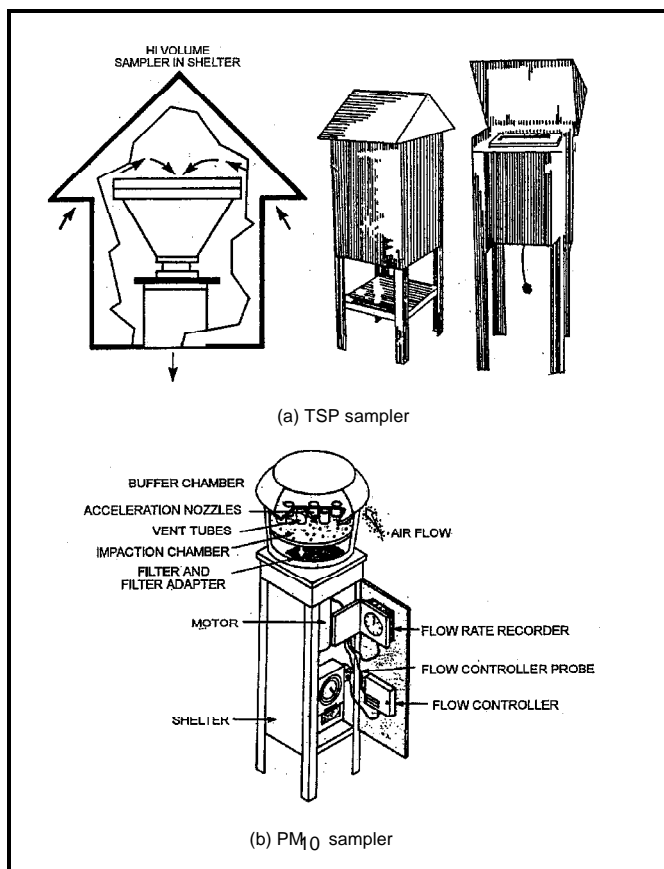


Figure 5-25. Example of (a) TSP sampler and (b) PM₁₀ sampler

- Chemical stability.
- Temperature stability.
- Blank concentrations.
- Flow resistance and loading capacity.
- Cost and availability

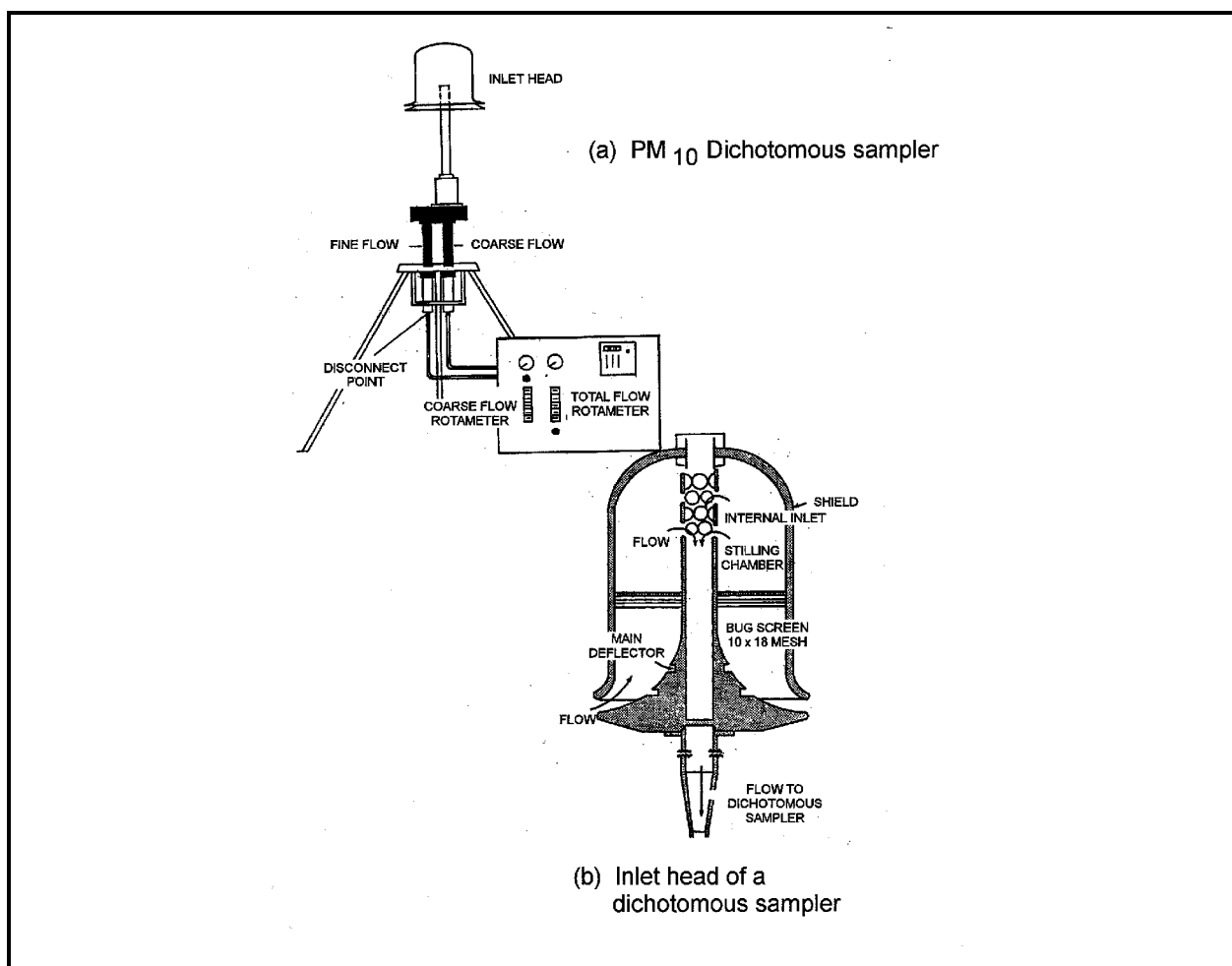


Figure 5-26. Example of PM₁₀ dichotomous sampler (a) and inlet head (b)

A comparison of several air sampling filter types is presented in Table 5-8 with the chemical and physical characteristics and the corresponding chemical analytical methods that can be used for analysis of the sample.

Table 5-8
Example of Types of Filter Media for Particulate Sampling

Filter type	Filter sizes (mm)	Characteristics		
		Chemical	Physical	Analysis Methods
Ringed Teflon membrane	25	<ul style="list-style-type: none"> • Low blank levels • Low blank weight • No carbon analysis • Low hygroscopic tendency • Inert to gas adsorption 	<ul style="list-style-type: none"> • White, nearly transparent surface • Minimal diffusion of transmitted light • High flow resistance • High particle collection efficiency • Melts at 60°C • Multiple pore sizes available • Cannot be accurately sectioned 	<ul style="list-style-type: none"> • XRF, PIXE, NAA, AA, ICP/MS, Gravimetry (GRAV.), Optical Adsorption (OA), Ion Chromatography (IC), and Automated Colorimetry (AC)
	37			
	47			
Teflon membrane--polypropylene backed	47	<ul style="list-style-type: none"> • Low blank levels • High blank weight • No carbon analysis • Low hygroscopic tendency • Inert to gas adsorption • High background levels for PIXE and XRF 	<ul style="list-style-type: none"> • White opaque surface • Diffuses transmitted light • High flow resistance • High particle collection efficiency • Melts at 60°C 	<ul style="list-style-type: none"> • Grav., PIXE, XRF, NAA, AA, ICP, ICP/MS, IC, AC
	25			
	37			
Nylon membrane	25	<ul style="list-style-type: none"> • Low blank weight • Low hygroscopic tendency • High HNO₃ collection efficiency • Passive adsorption of low levels of NO, NO₂, PAN, and SO₂ 	<ul style="list-style-type: none"> • Diffuses transmitted light • High flow resistance • Melts at 60°C • 1 µm pore size 	<ul style="list-style-type: none"> • IC, AC
	37			
	47			
Silver membrane	25	<ul style="list-style-type: none"> • High blank weight • Low hygroscopic tendency • Resistant to chemical attack • Passive adsorption of organic vapors 	<ul style="list-style-type: none"> • Gray-white surface • Diffuses transmitted light • High flow resistance • Melts at 350°C 	<ul style="list-style-type: none"> • Grav., X-ray Diffraction (XRD)
	37			
Cellulose esters membrane (cellulose nitrate mixed esters and cellulose acetate)	37	<ul style="list-style-type: none"> • Low blank weight • Highly hygroscopic • Dissolved by several organic solvents • Negligible ash content 	<ul style="list-style-type: none"> • White opaque surface • Surface diffuses transmitted light • High flow resistance • Melts at 70°C • Multiple pore sizes available 	<ul style="list-style-type: none"> • Grav., Optical Microscopy (OM), Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), XRD
	47			

(continued)

Table 5-8 (continued)
Example of Types of Filter Media for Particulate Sampling

Filter type	Filter sizes (mm)	Characteristics		
		Chemical	Physical	Analysis Methods
Polycarbonate membrane	47	<ul style="list-style-type: none"> Low blank levels Low blank weight No carbon analysis Low hygroscopic tendency 	<ul style="list-style-type: none"> Light gray, nearly transparent surface Minimal diffusion of transmitted light Moderate flow resistance Low particle collection efficiency for some pore sizes Melts at 60°C Multiple pore sizes available Use for particle size classification Retains static charge 	<ul style="list-style-type: none"> Grav., OA, OM, SEM, XRF, PIXE
Pure quartz filter	25 37 47 203 x 254	<ul style="list-style-type: none"> Low blank level for ions Contains large and variable quantities of Al and Si Low hygroscopic tendency Passive adsorption of organic vapors Little adsorption of HNO₃, NO₂, and SO₂ 	<ul style="list-style-type: none"> White opaque surface Diffuses transmitted light Moderate flow resistance High particle collection efficiency Melts at >900°C Edges of filter flake in holders 	<ul style="list-style-type: none"> ICP, ICP/MS, IC, Thermal Carbon Analysis (TCA), Thermal Optical Transmission Carbon Analysis (TOT) Thermal Manganese Oxidation Carbon Analysis (TMO)
Mixed quartz fiber (quartz filters with 5% borosilicate content)	203 x 254	<ul style="list-style-type: none"> Contains large and variable quantities of Na, Al, and Si plus variable levels of other metals High blank weight Low hygroscopic tendency Passive adsorption of organic vapors Little adsorption of HNO₃, NO₂, and SO₂ 	<ul style="list-style-type: none"> White opaque surface Diffuses transmitted light Low flow resistance High particle collection efficiency Can melt at 500°C Becomes brittle on heating 	<ul style="list-style-type: none"> Grav., XRF, PIXE, AA, ICP, ICP/MS, IC, AC, T, TOR, TMO, TOT

(continued)

Table 5-8. (continued)
Example of Types of Filter Media for Particulate Sampling

Filter type	Filter sizes (mm)	Characteristics		
		Chemical	Physical	Analysis Methods
Teflon-coated glass fiber (borosilicate glass fiber mat with surface layer of Teflon)	37 47	<ul style="list-style-type: none"> Low blank level for ions High blank weight Low hygroscopic tendency Inert to adsorption of HNO₃, NO₂, and SO₂ 	<ul style="list-style-type: none"> Low flow resistance High particle collection efficiency Melts at 60°C; glass at 500°C 	<ul style="list-style-type: none"> Grav., IC, AC
Glass fiber (borosilicate glass fiber)	203 x 254	<ul style="list-style-type: none"> High blank levels High blank weight Low hygroscopic tendency Adsorbs HNO₃, NO₂, SO₂, and organic vapors 	<ul style="list-style-type: none"> White opaque surface Diffuses transmitted light Low flow resistance High particle collection efficiency Melts at 500°C 	<ul style="list-style-type: none"> Grav., OA, XRF, PIXE, NAA, AA, ICP, IC, AC
Cellulose fiber ("paper" filter)	25 37 47	<ul style="list-style-type: none"> Low blank levels; high purity High blank weight No carbon analysis Highly hygroscopic Most useful for adsorption of gases, e.g., HNO₃, SO₂, NH₃, and NO₂ after impregnated with reactive chemicals 	<ul style="list-style-type: none"> White opaque surface Diffuses transmitted light Variable flow resistance Low particle collection efficiency possible Burns at 150°C High mechanical strength 	<ul style="list-style-type: none"> Grav., XRF, PIXE, NAA, AA, ICP, ICP/MS, IC, AC

Quartz fiber filters are the most commonly used filters for TSP/PM₁₀ particulate sampling for determining mass loading as part of a collocated monitor in a FFMS. They are constructed from finely spun glass fiber and an organic binder compressed in a paper machine. They are quite fragile and must be handled with care. However, these filters have the ability to withstand high temperatures (up to 540°C). They are further typified by high-collection efficiency. In some cases, the organic binder may interfere with subsequent analysis, so the filter is flash-fired to remove the binder material. Quartz filters are nonhygroscopic, thus able to be used in areas where humidity is high. Because they are glass, they are the filter choice for most corrosive atmospheres. Because of their high silicate content, they are extremely difficult to ash by chemicals or heat. Therefore, extraction procedures are performed on these filters to remove the sample for subsequent chemical analysis. For this reason, flash-fired quartz filters are the preferred filter of choice as part of a collocated monitor in a FFMS.

(2) Equivalent methods. Equivalent or real-time methods for measuring TSP and PM₁₀ rely on instruments equipped with either a radiometric detection device or an oscillating pendulum detection device. To date, the EPA has designated only two radiometric instruments and one oscillating pendulum instrument as equivalent methods. These are the Graseby and Thermo Environmental Beta Gauge instruments and the Rupprecht and Pataschnick (R&P) TEOM® Monitor, respectively.

As discussed in Chapter 4 and illustrated in Figure 5-27, the operation of the beta gauge involves particulate material being accumulated on a continuously moving filter tape that is passed between a source of low-energy

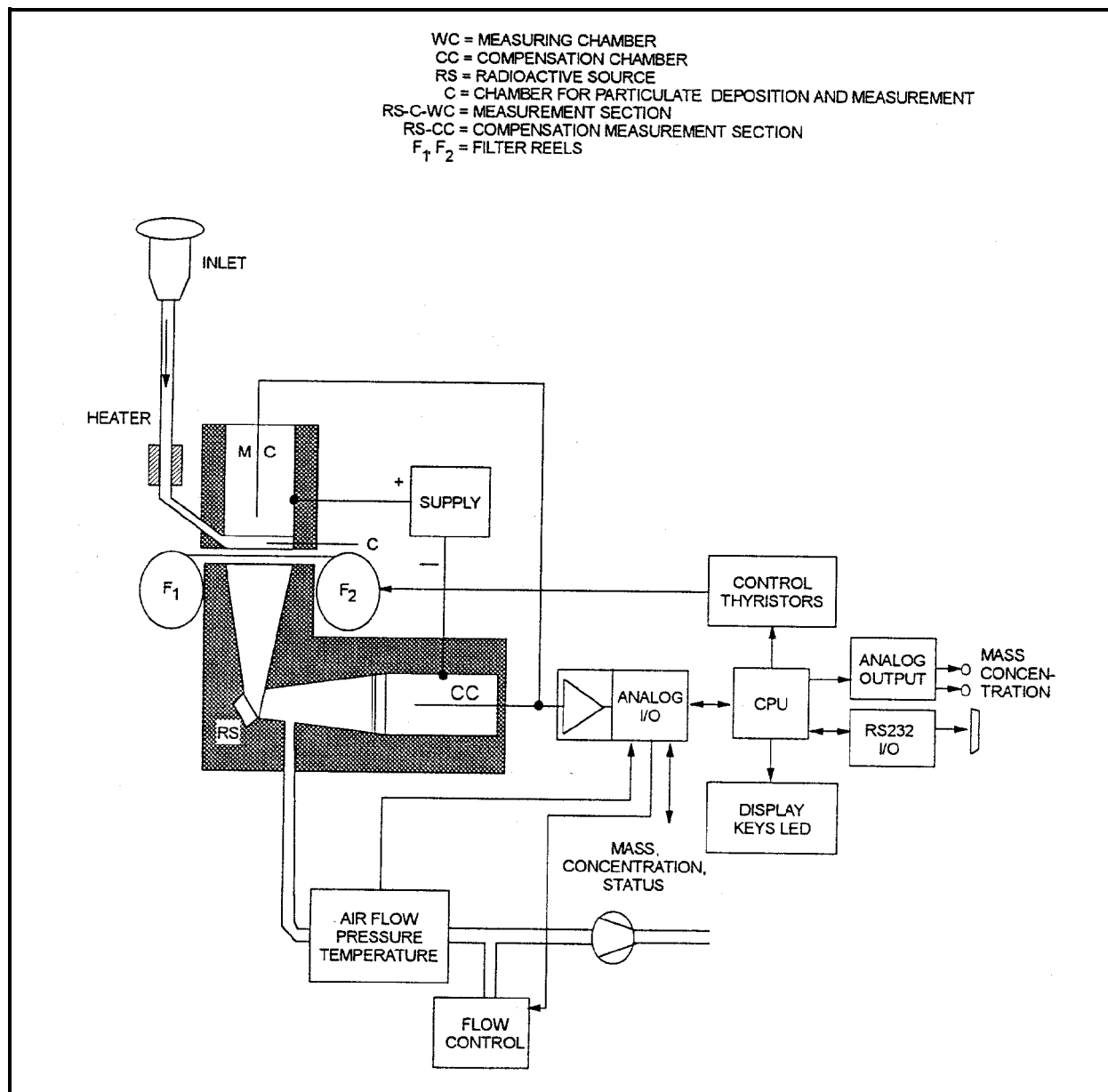


Figure 5-27. Example of operation of a typical commercial PM_{10} beta-gauge sampler

beta rays (i.e., 0.01 to 0.1 MeV electrons) and a detector at a designated feed rate. Beta radiation is attenuated by the filter tape according to the approximate exponential function of particulate mass loading (i.e., Beer's Law). Attenuation of blank filter tape prior to particulate loading, or some other "control" material, is also measured for comparison. The difference in attenuation between the blank and exposed filter is calculated as the blank corrected particulate mass concentration for the specific time period of exposure as determined by the tape feed rate. Beta gauge samplers are operated at a relatively low flow rate (nominally 16.7 liters/minute) with sampling

inlets designed for either TSP or PM₁₀ size fractionation. While these monitors are capable of mass concentrations for averaging times as short as 30 minutes, 2-to 24-hour averaging periods are frequently required with typical ambient concentrations to obtain sufficient particulate deposition for an accurate determination.

The Rupprecht and Pataschnick tapering element oscillating microbalance (TEOM®) monitor shown in Figure 5-28 is based on an altogether different measurement principle. With this monitor, particulate is continuously accumulated on an exchangeable filter cartridge. The filter cartridge is fixed to a patented measurement device consisting of a TEOM®. Particle-laden air enters the monitor through a size fractionating sample inlet and then passes through the tapering element, which consists of a hollow glass tube that oscillates in an applied electric field. Particulate matter is deposited on the filter cartridge, which is mounted at the tip of the tapering element. Since the frequency of oscillation of the tube and filter is proportional to their combined inertial mass, particulate loading can be continuously measured. The monitor continuously measures particulate mass at concentrations between 5 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) and several grams per cubic meter (g/m^3). Mass loading rate, mass concentration, and total mass accumulation may be calculated. The exchangeable filter cartridges are designed to allow for future chemical and physical analysis. The monitor can be operated as either a TSP monitor or as a PM₁₀ monitor, depending on the sampling head attached. Further size fractionation is possible with an optional sampling head designed to pre-separate particles at 2.5 and 10 μm diameter cut points. Both the beta and oscillating microbalance techniques are fully discussed in Chapter 2, Methods IO-1.1 through IO-1.3, as part of EPA's *Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air*.

Each of the reference and equivalent methods described above has its own unique operational requirements and characteristics. Obviously, each method has its own advantages and important interferences to be aware of. The most important of these factors are outlined in Table 5-9.

b. Sampling activities. As with other types of fence-line monitoring activities, particulate sampling is generally scheduled in coordination with remedial activities at the HTRW site. Often, several phases of a sampling program are planned to coincide with or precede the mobilization, construction, and operation phases of the remediation project. Phases typically include background monitoring, an intense (high frequency, multi-sampler, multi-analyte) start-up monitoring phase, and long-term monitoring.

Sampling activities generally include equipment mobilization or set-up, sampler calibration (initial and field), routine operation and maintenance of samplers, preparation and recovery of samples, and sample storage and transport. Appropriate procedures for each of the methods described above are outlined in detail within the Federal Register method references, the *Compendium Methods for the Determination of Inorganic Compounds in Ambient Air*, and instrument operating manuals available from individual vendors.

c. Siting requirements and location. The number and locations of TSP/PM₁₀ samplers used in fixed-fence-line monitoring systems are determined on the basis of several factors. These generally include:

- The purpose(s) of the sampling program and data quality objectives.
- The size and shape of the waste site.

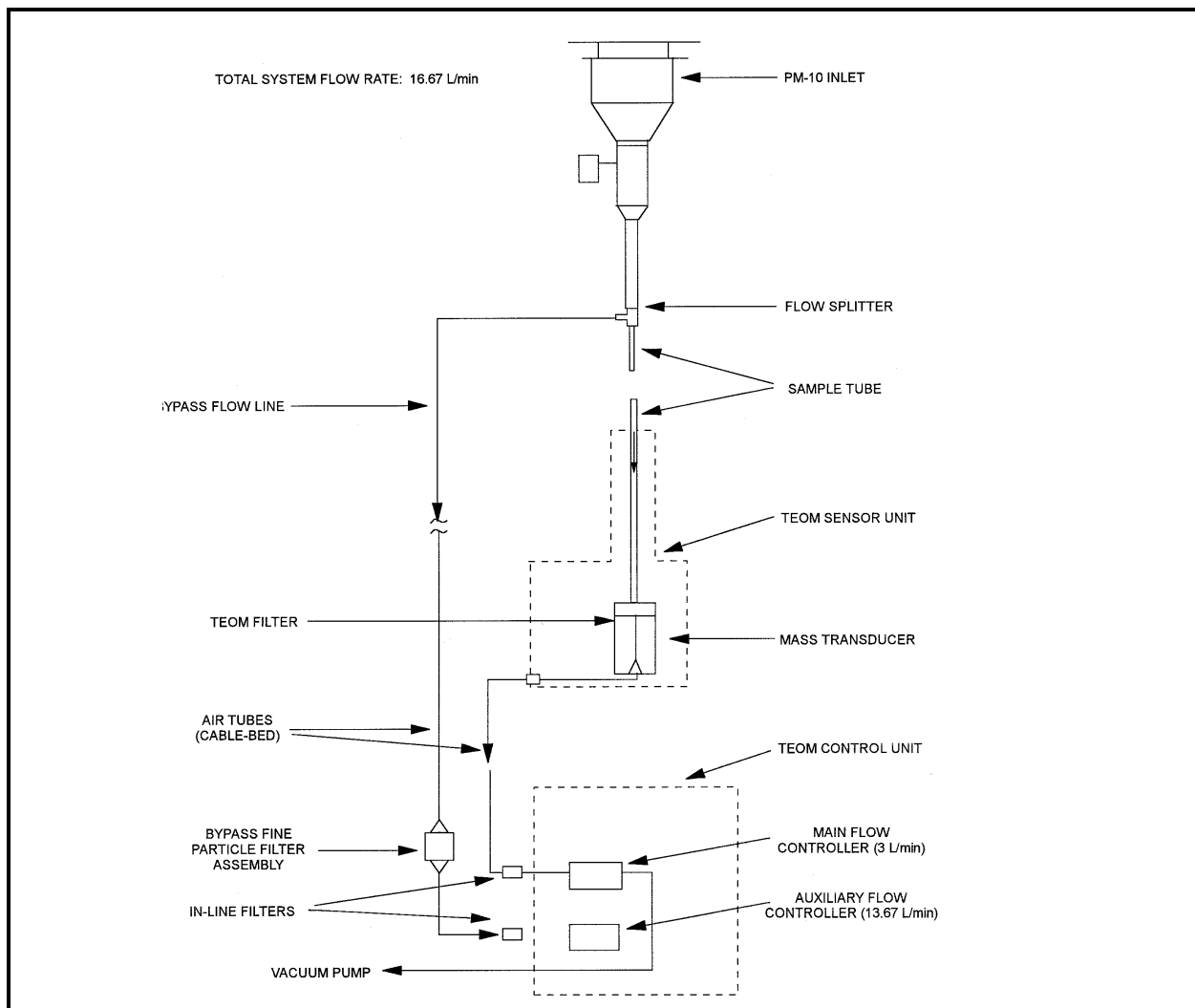


Figure 5-28. Example of a real-time PM₁₀ sampler based upon the oscillating microbalance (TEOM®) technique

- The locations of potential on-site emission sources.
- The locations of topographic features that affect the dispersion and transport of site emissions
- The variability of local wind patterns.
- The locations of sensitive receptors such as schools, hospitals, and concerned citizens.
- The level of available funding.

Table 5-9
Example of Advantages/Disadvantages of Particulate Sampling Methods

Sampler Type	Advantages	Disadvantages
Hi--Vol Methodology	<ul style="list-style-type: none"> High flow rate = more material captured = lower detection of ambient concentrations of inorganic materials (assuming identical filter medium and analysis technique). Volumetric flow control ensures constant flow rate. Highly durable and versatile. 	<ul style="list-style-type: none"> Filter may cause plugging and stress motor. Weather can cause variable flows Equipment and electrical not very durable in bad weather
Dichotomous Methodology	<ul style="list-style-type: none"> Collects two fractions so information can be obtained about total PM₁₀ and either/or both of the two fractions. Analysis by XRF. Operates at a low flow rate (about 0.6 ft³/min) allowing use of filter media that would otherwise quickly clog at hi-vol flow rates. 	<ul style="list-style-type: none"> Filters may plug during sampling in inclement weather from rain. Tripod needs to be secure to the sampling platform.
Beta-Gauge Methodology	<ul style="list-style-type: none"> Measurement mechanism has no moving parts. Heating of sample air stream generally not required. Less sensitive to fluctuations of ambient temperature, pressure and humidity. 	<ul style="list-style-type: none"> May require a license from Nuclear Regulatory Commission for radioactive source. Only authorized personnel can repair source. Generally requires some protection from internal condensation.
Oscillating Microbalance Methodology	<ul style="list-style-type: none"> Can provide highly precise measurements for averaging periods of 1-hour or less. 	<ul style="list-style-type: none"> Must be isolated from excessive mechanical noise and vibration. Constant internal temperature must be maintained above ambient field temperature.

Typically, programs designed for determining long-term concentration levels or public health impacts require fewer monitoring locations than those intended to monitor compliance with short-term action levels because the long-term prevailing wind directions are usually more predictable than day-to-day wind patterns; therefore, samplers can be more accurately situated for measuring significant long-term effects. Dispersion modeling of source emissions, using climatological data as input, is often performed to determine the most appropriate sampling locations (i.e., areas of maximum or significant effects).

For determining concentration levels with respect to short-term effects, a fixed network of samplers ideally should be located around the perimeter of the HTRW site, with additional samplers located near working areas and near sensitive receptors. The number of samplers will depend, primarily, on the size and shape of the HTRW site. For large sites surrounded by nearby residences, a 12-station network would provide nearly complete spatial coverage of the fenceline (i.e., one sampling station every 30°). In some cases, only samples from stations located directly upwind or downwind of the site for a given sampling period might need to be analyzed. Alternatively, for smaller sites, fewer receptors, and/or smaller budgets, a smaller number of stations may be used; possibly as few as one sampling station in each compass quadrant. The minimum and maximum number of recommended monitoring locations for a typical HTRW site are shown in Figure 5-29.

As illustrated in Figure 5-29, the location of time-integrated with real-time perimeter volatile organic monitoring systems may be controlled by the Analytical Center coupled with the on-site meteorological station. In essence, during periods of on-site remediation, the Analytical Center would sense the wind direction from the meteorological station and turn-on the time integrated TSP/PM₁₀ monitors to operate only when the wind comes from the upwind quadrant. Under this scenario, sampling would occur only during periods of upwind designation, thus the user is able to determine upwind/downwind concentrations and the effect of the remediation activities on the surrounding community. This approach limits the number of samplers to be purchased and the number of samples to be analyzed. Sampling may, however, require several days to obtain enough sample for analysis, especially with the determination of metals from the filter material.

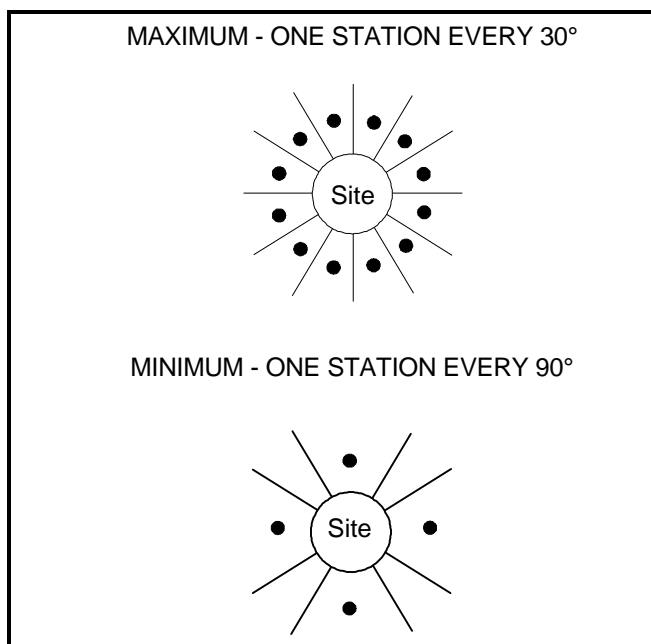


Figure 5-29. Depiction of maximum and minimum number of recommended monitoring locations for a typical HTRW site

Similar to other monitoring systems, sampler placement is very important to ensure a representative sample is obtained. In many cases, wind flow obstructions caused by nearby buildings, trees, hills, or other obstacles may constrain sampler placement. Other constraints might be related to security, the accessibility of electrical power, or the proximity to roadways and other pollution sources that might affect the representativeness of the sample. Specific guidelines for selecting sites to achieve representative conditions are listed in Chapter 5, Paragraph 3c and repeated here:

- The most desirable height for sampler inlets is near the breathing zone (i.e., about 5 to 6 ft above ground). Practical factors, such as high impermeable fences surrounding the waste site, may sometimes require that sampling inlets be placed slightly higher (at least 1 meter above the top of the fence).
- Samplers should be located at least 20 meters from the dripline of nearby trees and must be at least 10 meters from the dripline of trees when the trees act as an obstruction to airflow.
- Samplers must be located away from obstacles and buildings such that the distance between the obstacles and the sampler inlet is at least twice the height that the obstacle extends above the sampler inlet. Airflow must be unrestricted in an arc of at least 270° around the sampler, and the predominant wind direction for the season of greatest pollutant concentration potential must be included in the 270° arc.
- The sampler and nearby roadways must be sufficiently separated to avoid the effects of dust re-entrainment and vehicular emissions on measured air concentrations.

- Stations located in unpaved areas should be placed on ground covers so that the effect of locally re-entrained or fugitive dusts will be kept to a minimum.

A properly collocated time-integrated TSP/PM₁₀ and inlet probe for a real-time volatile organic monitoring system is pictured in Figure 5-24 and diagrammed in Figure 5-30. When utilizing collocated sites, each of the samplers must be separated by a minimum of 6 feet so representative parcels of air can be extracted by each unit. In addition, the sampler inlets must be at a minimum of 6 feet above the ground. The sampler platform should be anchored (2 feet) in cement. All electrical connections must be protected from the elements. Two receptacles should be installed for more complex collocated systems, as illustrated in Figure 5-30. It is recommended that the system be secured with a chain-link fence and outdoor lighting.

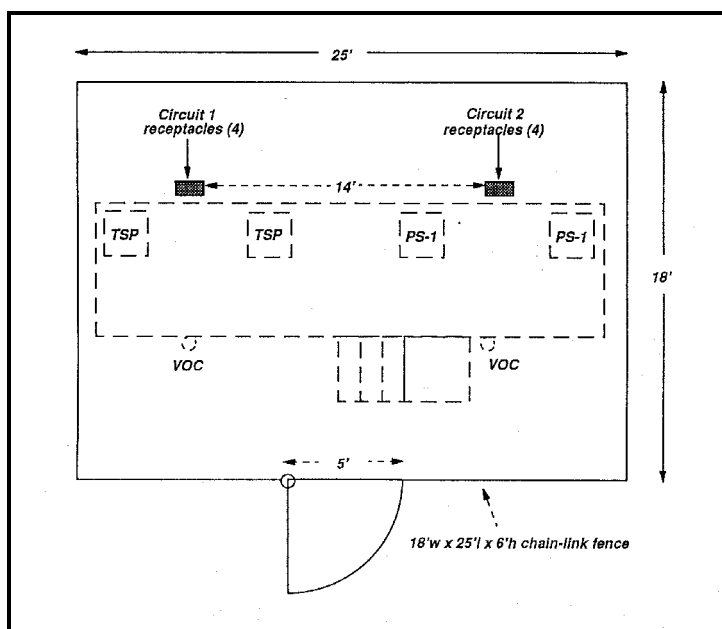


Figure 5-30. Example of a diagram of a collocated TSP and VOC inlet samplers

d. Sampling periods and frequencies. Sampling period refers to the length of time to which each measurement value is referenced (e.g., 30-minute, 1-hour, 24-hours, etc.). The sampling frequency is the number of sampling periods conducted within a given time interval (e.g., daily, one every third day, etc.). For typical HTRW monitoring programs, the sampling period may range from a few seconds to 72 hours, depending on the specific goals and data requirements of the program. Sampling periods of a few seconds are performed using real-time or grab sampling techniques, whereas longer sampling periods are usually performed using time-integrated methods. For real-time monitoring, the sampling frequency is usually continuous, although sampling may be limited to certain times of the day when remedial activity is occurring. Time-integrated sampling may be performed continuously (i.e., back-to-back sample collection, or at intermittent, discrete

intervals. Specific program goals and available funding will normally dictate whether continuous or intermittent sampling intervals are performed. Grab sampling is only performed when an instantaneous spot check of the air constituents is required (e.g., as a pre-monitoring screen for constituent compounds), or is a specified corrective action.

Sampling periods must be chosen for comparability with relevant action levels or ARARs. For example, if the measurement data are to be compared with a 30-minute action level, a 30-minute sampling period is normally required (alternatively, continuous, real-time monitoring can be performed and the resulting data averaged over 30-minute intervals). Compliance with long-term action levels usually is determined using a series of 24-hour sampling periods. In some cases, sampling periods also may depend on the amount of sample volume needed

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to achieve acceptable detection limits. A 1-hour sampling period, for instance, will yield a detection limit one-half that of the same technique operating with the same flow rate for 30 minutes.

The required frequency of sample collection depends primarily on:

- The variability of emission rates with respect to the time period associated with the action level.
- The variability of meteorological and other factors that might affect pollutant dispersion.
- The level of confidence needed for determining mean or maximum downwind concentrations.
- The level of available funding.

When action levels are based on short-term averages and the pollutant concentrations are expected to vary significantly over time, continuous sample collection may be needed to achieve an acceptable level of confidence that PALs are not exceeded. Note that the level of confidence required in the measurement results may depend on how close the measured ambient concentration levels are to the action level concentrations (i.e., the higher the measured concentrations, the greater the confidence required). For determining compliance with long-term action levels, a minimum sampling frequency of once every sixth day is normally required. However, if the measured concentration levels are near levels of concern, a greater frequency of collection, perhaps daily, will be required (e.g., operating schedule for PM₁₀ sampling given in 40 CFR, Part 58. 13).

5-8. Verification of the Sample Collection System

Proper performance of the collection system should be verified regularly by measuring a number of critical parameters at selected locations along the sample path. The purpose of QC checks is to demonstrate that sample integrity is not lost during travel through the sample collection system. Sample integrity may be compromised through system leakage, system plugging, internal condensation of contaminants and/or water vapor, or absorption of contaminants on internal surfaces. Parameters typically included are various flow rates, pressures, temperatures, electrical resistances, and transfer efficiencies. The frequency of these checks will depend on the expected stability of the specific parameter. Table 5-10 provides a summary of the parameters that should be verified and recommended frequencies for these checks

The primary parameter requiring verification for the collection system is transfer efficiency as measured by percent recovery of gas sample of known concentration. An 80 to 120 percent tolerance recovery is typical. Measurements exceeding the tolerance threshold should trigger diagnostic procedures and/or corrective action. Secondary parameters needing verification are measurements of flow rates, pressures, sample line temperatures, and electrical resistances. Tolerances for each of these parameters should be established during system design based on the manufacturer's performance specifications for specific collection system components such as pumps and heated sample lines.

Figure 5-31 illustrates a typical equipment set-up for both a transfer efficiency check and a flow rate check of a FFMS collection system. As shown, flow rate is simply measured by attaching a rotameter to the sample inlet. For transfer efficiency, a supply of standard gas of known concentration is introduced at the sample inlet, drawn

Table 5-10
Example of Typical Collection System Audit Parameters

Audit Parameter	Measurement Location	Suggested Minimum Frequency	Application
Sample transfer efficiency	<ul style="list-style-type: none"> introduction of standard gas at sample inlet 	Weekly	Verification that sample integrity is maintained
Flow rate	<ul style="list-style-type: none"> at sample inlet at sample pump at various ports to the analytical system 	Weekly	Verification of unrestricted sample flow
Sample line temperature	<ul style="list-style-type: none"> at heat trace sample line control panel at junction box between each heat trace sample line segment 	Each shift any weekly	Verification of performance of heat trace sample line according to specification
Sample line resistance	<ul style="list-style-type: none"> at junction box between each sample line segment 	Weekly	Verification of performance of heat trace sample line according to specification
Operating gas pressures	<ul style="list-style-type: none"> at carrier gas canister at calibration gas canisters at auxiliary air compressor 	Daily	Verification of performance operating gas supply according to specification

through the heated sample line by the primary sample pump, delivered to the sample conditioning system, and presented to the analytical system in the Analytical Center for quantitation. To accurately simulate actual sampling conditions, the pressurized standard gas must be introduced at the sample inlet at atmospheric pressure. Therefore, either a flow-through Tedlar[®] bag or a more elaborate equilibration apparatus with a sensitive pressure gauge is used. Experience has shown the Tedlar[®] bag arrangement to be the most reliable and simple to operate in the field, as illustrated in Figure 5-31.

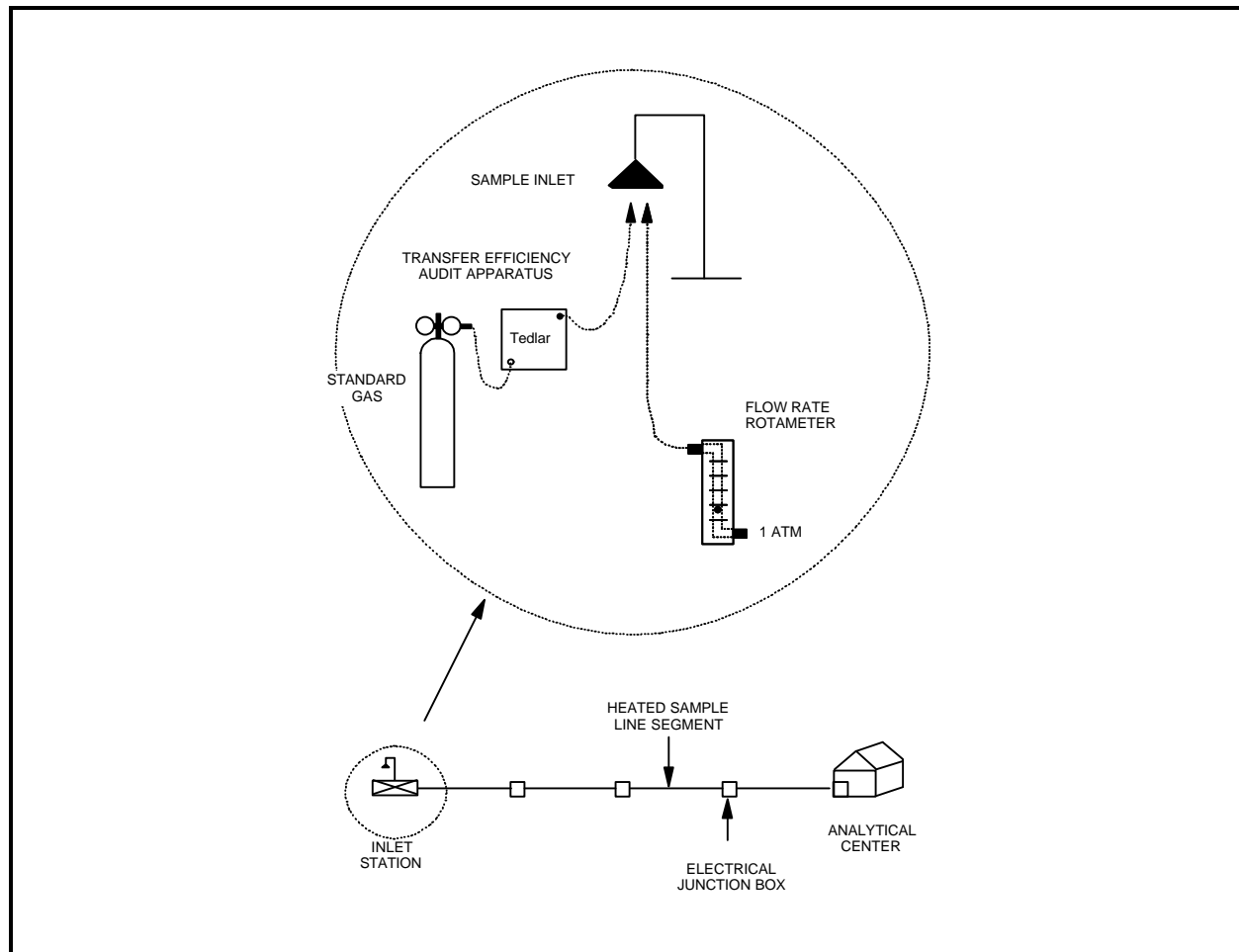


Figure 5-31. Example of QC procedures for evaluating transfer efficiency and flow rate of a FFMS